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JOURNAL OF CHEMICAL EDUCATION

for September, 1937

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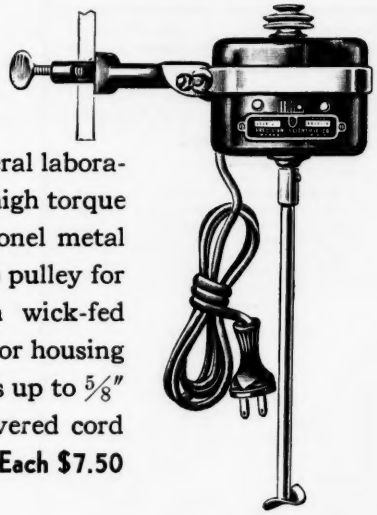

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LABORATORY APPARATUS AND CHEMICALS

WILHELM KÖRNER (1839–1925)

Körner was a collaborator of August Kekulé and Stanislao Cannizzaro; afterward, he was professor of chemistry in Milano, Italy. His work is especially connected with Kekulé's formula of benzene. He was the first to determine the "chemical place" in the aromatic compounds (1:2, 1:3, 1:4). He explained the construction of resorcin and worked on pyridine.

For note about the Kekulé Album contributed by Dr. E. Berl, of Carnegie Institute of Technology, see page 407. Dr. Berl also lent the photograph here reproduced.

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EDITOR'S OUTLOOK

"WE GOT RIGHTS." A great deal of absurd nonsense on the subject of "human rights" has been perpetrated in the past few years. Absurdity and nonsense are no news in these United States, and no single example would call for serious comment save for the growing evidence that much which once passed for sincere, though visionary, blather is actually wilfully vicious in intent and insidiously destructive in effect.

In a state of nature, man, like any other animal, may enjoy such goods and privileges as he is strong and cunning enough to acquire and hold. At a slightly higher level he learns that the acquisition of goods may be facilitated and the enjoyment of privileges safeguarded by coöperative action. Eventually he learns to exchange surplus goods for those of which he has need, to exchange services for goods or vice versa, and to forego the privilege of tossing tin cans in the neighbors' back yards in return for reciprocal restraint on their part.

These simple elements are the basis of all "human rights." Complicate them as we will with monetary systems, governmental bureaucracies, and other complexities of modern civilization, there is no ultimate escape from the fundamental facts. One produces what he needs, barters other goods or services for it, seizes it by force, depends upon charity, or goes without. There can be no "rights" to goods and privileges that in the nature of things do not exist; there can be no "right" to that which one lacks the industry, intelligence, and adaptability to earn for himself, save the right of seizure.

The "rights" of the sub-marginal agricultural producer, or of the inefficient and indolent workman to a living wage, the "rights" of the indigent aged to security, the "rights" of the unemployed to support at public expense, in so far as they exist at all, are simply the rights of seizure. So long as the more fortunate and more provident of us carry their weight as well as our own, they should have little to say of "rights." If they fear that we shall weary of the burden, they and their demagogic leaders should carry blackjacks and speak frankly of the right of seizure—if they are strong enough to exercise it.

The simple truth of the matter is, of course, that the right of seizure would avail them little. There just isn't enough work being done, or enough goods in existence, to give everyone all that he thinks he "has a right to." Moreover, while the grasshoppers may get through one tough winter by liquidating the ants, things will be a lot tougher for them the year after.

We have Mr. Hopkins' word for it that he, his peerless leader, and his colleagues have succeeded in the permanent pauperization of a considerable portion of our population. The real danger is, however, that their specious propaganda is misleading an entire generation into intellectual and moral pauperism. If there be any academic Don Quixotes who consider it a teacher's duty to take an occasional tilt at social windmills, this one labeled "human rights" needs pushing over.

J. A. ARFWEDSON *and* HIS SERVICES *to* CHEMISTRY*

MARY ELVIRA WEEKS AND MARY E. LARSON

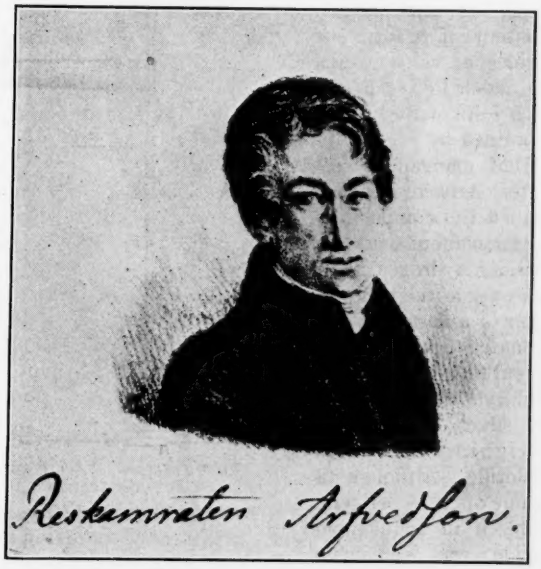
University of Kansas, Lawrence, Kansas

ALTHOUGH the histories of chemistry devote but little space to the work of J. A. Arfwedson, the discoverer of lithium, Berzelius' correspondence, travel-diary, and autobiography contain much interesting information about him. The superb biography of Berzelius which the late H. G. Söderbaum completed near the close of his life also throws much light on Arfwedson's chemical activity.

Johan August Arfwedson was born in January, 1792,†[1,2] on the family estate at Skagerholms-Bruk in Skaraborg County, Sweden. Until the age of fourteen, he was educated at home, and in 1806 he entered the college (högskolan) at Upsala. After completing the mining course at Upsala, he entered the Royal College of Mines at Stockholm, where he pursued the regular course, served as secretary at the school, and still found time to carry on research in chemical analysis in Berzelius' famous laboratory. When the twenty-five-year-old Arfwedson entered this laboratory early in 1817, he had among his classmates Count H. G. Trolle-Wachtmeister, ten years his senior, and Lieutenant C. A. Arrhenius, the discoverer of gadolinite, who was then sixty years of age.

Arfwedson immediately set to work analyzing meïonite and leucite.[3,4,5] He observed that although the leucite was very infusible, the meïonite melted readily before the blowpipe, swelled, and formed an enamel. Since his analysis of meïonite agreed closely with Klaproth's analysis of leucite, Arfwedson analyzed a specimen of leucite and found these two minerals to be very similar in composition, except that the leucite contained no lime. Suspecting, therefore, that the lime must be the cause of the meïonite's fusibility, he mixed a little lime with the leucite, after which it, too, could be easily melted.

In the autumn of the same year, Arfwedson completed a beautiful research on the oxides of manganese. He determined the per cent. of manganese in the brown powder obtained by igniting manganous oxide and in the black powder, manganic oxide, obtained by evaporating this brown manganosic oxide with nitric acid and gently igniting the residue. Since he found it difficult to get the black powder of constant composition, he recommended that in analytical work the oxide should always be strongly ignited and weighed as manganosic oxide.



Courtesy Mr. Carl Björkbom, Royal Library, Stockholm

JOHAN AUGUST ARFWEDSON, 1792–1841

This lithograph by Fehr and Müller of Stockholm was labeled by Berzelius "Reskamraten Arfvedson" (traveling companion Arfvedson). Berzelius placed it in the manuscript of his travel diary "Reseanteckningar."

Arfwedson also observed that the ratio of the oxygen in manganous oxide to the oxygen in manganic oxide is as 1 to $1^1/_2$, a relation which the modern chemist expresses in the formulas MnO and Mn_2O_3. He realized that manganosic oxide must be a compound of these two oxides, and reasoned that "if this compound, like ferrous-ferric oxide, may be supposed to be of such compo-

* Presented before the Divisions of History of Chemistry and Chemical Education at the Midwest Regional Meeting of the A. C. S., Omaha, Nebraska, April 30, 1937.

† Söderbaum[1] and Leijonhufvud[2] give the date of Arfwedson's birth as January 4th; the unsigned obituary[4] in the *Kongl. Vet. Acad. Handl.* gives it as January 12th.

[1] B. BOETHIUS, "Svenskt biografiskt lexikon," A. Bonnier, Stockholm, **1918.** Article on Arfwedson by H. G. Söderbaum.

[2] K. A. K:SON LEIJONHUFVUD, "Ny svensk släktbok," P. A. Norstedt & Söner, Stockholm, **1906,** pp. 94–5.

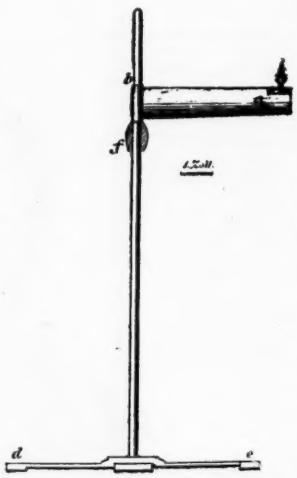
[3] H. G. SÖDERBAUM, "Berzelius levnadsteckning," Almqvist & Wiksells Boktryckeri A.-B., Upsala, **1929,** 3 vols.

[4] ANON., "Biografi öfver Johan August Arfvedson, Bruks-patron," *Kongl. Vet. Acad. Handl.*, **1841,** pp. 249–55.

[5] ARFWEDSON, "Analys af meïonit dioctaèdre och af leucit från Vesuvius," *Afh. i Fysik, Kemi och Mineralogi*, **6,** 255–62 (1818).

sition that the oxide contains twice as much metal and three times as much oxygen as the protoxide, this compound consists of 72.82 per cent. metal and 27.18 per cent. oxygen . . . I have called this oxide *oxidum manganoso-manganicum* because of its resemblance to ferroso-ferric oxide, the composition of which Herr Professor Berzelius described in his *Attempt to lay the foundations of a purely scientific system for Mineralogy*, page 92."

Manganosic oxide is now known to contain only 72.03 per cent. of manganese. Since Arfwedson obtained 1.0735 grams of manganosic oxide by igniting one gram of manganous oxide, which is in good agreement with the value now accepted (1.0752 grams), his experimental work must have been excellent. In computing the per cent. of manganese in manganosic oxide, however, he made the mistake of accepting 21.88 per cent. as the oxygen content of manganous oxide, a value which Professor Johann Friedrich John of Berlin had obtained by the analysis of manganous sulfate. Arfwedson determined the composition of manganous oxide by passing hydrogen chloride over a weighed portion of manganous carbonate, treating the resulting manganous chloride with an excess of silver nitrate, and weighing the silver chloride. Although his value of 22.14 per cent. oxygen in manganous oxide was somewhat better than that of John (the value now accepted is 22.56 per cent.), Arfwedson lacked confidence in it and stated, "I have reason to suspect a slight admixture of oxide in the muriate I investigated, and therefore the result of my analysis is probably less reliable." In September, 1817, Berzelius reported Arfwedson's research in letters to Dr. Marcet and Gay-Lussac,[6] and in the following year Arfwedson published it in the *Afhandlingar i Fysik, Kemi och Mineralogi*,[7] the editorial staff of which he had recently joined.



From Berzelius' "Lehrbuch der Chemie"

BERZELIUS' BLOWPIPE LAMP

When he had completed the manganese research, Berzelius set him to work at analyzing a new mineral, petalite, from the iron mine on Utö, one of the many rocky islands or skerries which comprise Stockholm's superb archipelago. Arfwedson fused the petalite with potassium carbonate, determined the silica in the usual manner, and precipitated the alumina with ammonium carbonate. His analysis totaled only 96 per cent. Surprised to find such a large loss in such a simple analysis, he decomposed the petalite with barium carbonate. After removing the silica and alumina and the barium sulfate obtained by adding excesss ulfuric acid, he evaporated the washings, volatilized the ammonium salts, and found a fused residue of a soluble, non-volatile sulfate. Since an aqueous solution of this salt gave no precipitate with tartaric acid, "platina solution," or caustic potash, the base could be neither potash nor magnesia. Arfwedson therefore assumed that the salt must be sodium sulfate, but when he calculated his results on that assumption, his analysis totaled about 105 per cent. Thinking that this excess weight must be due to improper washing of his precipitates, he repeated the analysis twice and obtained in duplicate determinations 19.500 and 17.75 per cent. of the unknown sulfate.

In a letter to Wilhelm Hisinger, who was then analyzing the same mineral, Berzelius wrote on January 12, 1818, ". . . All these facts have led us to believe that petalite perhaps contains a new alkali . . . of such great saturating capacity that, when the salt is computed as a sodium salt, the excess in weight arises through the fact that the salt contains much less base than a sodium salt. If this be true, Arfwedson has had the good fortune to make in his second mineralogical analysis one of the most remarkable discoveries which can be made in this manner . . ."[8] Berzelius also announced Arfwedson's discovery of lithium to Dr. Marcet and Count Berthollet in the same letters in which he mentioned his own discovery of selenium.[8] Arfwedson's announcement of the discovery was published in the *Afhandlingar* in the same year.[9] According to Dr. Söderbaum,[8] Berzelius himself deserves a great deal of credit for the discovery of lithium as well as selenium, but was generous enough to let the lithium research be published under Arfwedson's name alone.

Arfwedson prepared lithium acetate, ignited it, and noted the insolubility of the resulting lithium carbonate in water and its action on platinum. He also prepared and studied the bicarbonate, sulfate, nitrate, chloride, tartrate, borate, hydroxide, and a double sulfate which he reported as lithium alum. He mentioned that lithium hydroxide is much less soluble than the other caustic alkalies and that it has a greater "saturation capacity" [lower equivalent weight] than they. Because of its ability to form deliquescent salts with nitric and

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[6] SÖDERBAUM, H. G., "Jac Berzelius Bref," Almqvist & Wiksells, Upsala, **1912–1914**, vol. 1, part 3, pp. 158–9. Letter of Berzelius to Marcet, Sept. 23, 1817; *Ann. chim. phys.*, (2), **6**, 204–5 (1817). Letter of Berzelius to Gay-Lussac, Sept. 28, 1817.

[7] ARFWEDSON, "Undersökning af oxidum manganoso-manganicum, en hittills okänd kemisk förening af manganoxidul och oxid," *Afh. i Fysik, Kemi, och Min.*, **6**, 222–36 (1818); *Annals of Philos.*, **23**, 267–75 (Apr., 1824).

[8] SÖDERBAUM, "Jac Berzelius Bref," Almqvist & Wiksells, Upsala, **1912–14**, vol. 1, part 1, pp. 63–4. Letter of Berzelius to Berthollet, Feb. 9, 1818; *ibid.*, vol. 1, part 3, p. 160. Letter of Berzelius to Dr. Marcet, Feb. 6, 1818.

[9] ARFWEDSON, "Undersökning af några vid Utö Jernmalmsbrott förekommande Fossilier, och af ett deri funnet eget Eldfast Alkali," *Afh. i Fysik, Kemi, och Min.*, **6**, 145–72 (1818); "Tillägg af Berzelius," *ibid.*, **6**, 173–6 (1818).

hydrochloric acids, Arfwedson recognized the close relation between the new alkali and the alkaline earths, especially magnesia.

His attempt to decompose the new base with Berzelius' galvanic battery of fifty pairs of plates in an electrolyte of sodium chloride was unsuccessful. As early as 1818, however, Sir Humphry Davy obtained a minute amount of lithium metal.[10] When he passed a current through fused lithium carbonate in a platinum capsule, "the alkali decomposed with bright scintillations, and the reduced metal being separated, afterwards burnt. The small particles which remained a few moments before they were reconverted into alkali . . . were . . . very similar to sodium. A globule of quicksilver made negative and brought into contact with the alkaline salt, soon became an amalgam of lithium, and had gained the power of acting on water. . . "

Most standard works of reference also contain incomplete statements that lithium was isolated by Brande (or Brandes) and refer to Scher., **8,** 120 or Schweigger's J., **8,** 120. The correct reference is Scherer's *Allgemeine Nordische Annalen der Chem.*, **8,** 120 (1822), which merely states that W. T. Brande used a voltaic pile to prepare lithium as a shining, white, combustible metal and refers to the second London edition of his "Manual of Chemistry," volume 2, page 57. This edition was published by John Murray in 1821. Brande's complete statement therein is as follows: "When lithia is submitted to the action of the Voltaic pile, it is decomposed with the same phenomena as potassa and soda; a brilliant white and highly combustible metallic substance is separated, which may be called *lithium*, the term *lithia* being applied to its oxide. The properties of this metal have not hitherto been investigated, in consequence of the difficulty of procuring any quantity of its oxide."*

In 1821 Arfwedson published a supplementary note to his lithium research,[11] in which he stated that the salt which he had previously reported as lithium acid sulfate must be the normal sulfate and that the double sulfate he had at first taken for lithium alum was really potassium alum resulting from a trace of potassium in his alumina.

In the summer of 1818 Arfwedson went to England taking with him specimens of Berzelius' new element selenium to present to Dr. Marcet, Sir Humphry Davy, and Dr. W. H. Wollaston as a gift from the discoverer. Berzelius met him there later and accompanied him on visits to Dr. Wollaston, William Prout, Sir Joseph Banks, F. C. Accum, William Allen, and the geologist John Farey, Senior. In company with Berzelius he studied at first hand the soda-water, gas, and brewing industries of England. In October of the same year the aged Abbé R. J. Haüy of Paris entertained Berzelius and Arfwedson and gave them some inspiring lessons on mineralogy.[12]

In June, 1819, Berzelius, Arfwedson, Alexandre and Adolphe Brongniart, and several other scientists made a geological tour of the Fontainebleau Forest and the country surrounding Clermont. Part of the journey was made in a crowded diligence in which "Arfwedson's slender form became still more compressed." At the inn in Clermont, Arfwedson, Almroth, and Berzelius finally relinquished one of their two wax candles to the insistent maid servant, who needed it for another guest, and continued their studies by the light of Berzelius' famous blowpipe lamp.

From Söderbaum's "Jac. Berzelius-Levnadsteckning"
JOHAN AUGUST ARFWEDSON
From a painting by J. Way.

The Mont-Dore region could be explored only on horseback. "I cannot mention," said Berzelius, "all the troubles I had (1) in getting my left foot up into its stirrup and (2) in throwing the right one so high up into the air that it arrived right over the little portmanteau which was tied back of the saddle . . . However, after several attempts, and after Almroth and Arfwedson had laughed to their hearts' content at my awkwardness, I finally succeeded."

On their journey to le Puy, their fellow passengers were good-natured, inquisitive peasants who thought the Swedish language was a kind of French patois. "Arfwedson," said Berzelius, "was, in their opinion, a prince, for he was wearing in the cabriolet the same suit he wore on the streets of Paris, whereas Almroth and I had adapted ourselves more to the dirty, careless traveling costume of the French."

In Lyons, Arfwedson and Berzelius observed the manufacture of silk and velvet in the homes of the

* This may serve as a correction to "The Discovery of the Elements," 3rd ed., p. 125.

[10] ANON., "Additional observations on lithium and selenium by Professor Berzelius," *Annals of Philos.*, (1), **11,** 374 (May, 1818); THOMAS THOMSON, "History of physical science from the commencement of the year 1817," *ibid.*, (1), **12,** 16 (July, 1818); ANON., "An account of the new alkali lately discovered in Sweden," *Quarterly J. of Sci. and the Arts*, **5,** 337–40 (1818); "Von Petalit und dem schwedischen rothen dichten Feldspath vom Dr. Clarke, Prof. der Mineralogie zu Cambridge," Gilbert's *Ann. der Physik*, **59,** 241–7 (1818).

[11] ARFWEDSON, "Tillägg och rättelser vid afhandlingen om lithion i Kongl. Vet. Acad. Handl för År 1818," *Kongl. Vet. Acad. Handl.*, **1821,** pp. 156–9.

[12] BERZELIUS, "Reseanteckningar," P. A. Norstedt & Söner. Stockholm, **1903,** 430 pp.

workers. In Geneva they visited Dr. and Mrs. Alexandre Marcet. While they were in Zurich, Professor M. A. Pictet of Geneva announced to them that they had both been elected to honorary membership in the Helvetian Scientific Society.

To simplify their journey across Prussia and homeward through Sweden, Arfwedson bought a fine carriage in Dresden. Berzelius and he visited the porcelain works at Berlin, where Berzelius bought several porcelain stopcocks and was delighted to find them completely airtight.

After their return to Stockholm in the winter of 1819, Arfwedson set up his own laboratory and equipped it with apparatus he had bought during his travels. In the following year he purchased a handsome estate at Hedensö (Heden's Island), where he equipped another chemical laboratory. However, since he owned the Näshulta Works and mill in Södermanland near Hedensö and shares in the Gravendal Works in Kopparberg and industrial plants at Skagerholm and Brunnsberg, his executive duties left him little time for research.

On April 18, 1821, he was elected to membership in the Swedish Academy of Sciences. In the same year he published some analyses of cyanite from St. Gotthard and Rörås and nepheline and sodalite from Vesuvius.[13] In 1822 he published analyses of cinnamon stone, chrysoberyl, and boracite.[14] He found the cinnamon stone which Berzelius had brought back from Vermland to be a calcium aluminum iron silicate and regarded it as a true garnet like the one from Ceylon which Klaproth had analyzed.

Arfwedson's analysis of Brazilian chrysoberyl was severely criticized by Thomas Thomson, who said that Arfwedson had "analyzed a considerable number of minerals with great care; but of late years he seems to have lost his activity. His analysis of chrysoberyl does not possess the accuracy of the rest; by some inadvertence, he has taken a compound of glucina and alumina for silica."[15] Glucina, or beryllia, had been discovered by L. N. Vauquelin nearly a quarter of a century before.[16]

Arfwedson fused the chrysoberyl three times with caustic potash in a silver crucible. Since a portion of the melt corresponding to about eighteen per cent. of the mineral failed to dissolve in hydrochloric acid, he reported this residue as silica. It is now known that beryllium hydroxide, when freshly precipitated, dissolves readily in hydrochloric acid, but becomes after a time almost completely insoluble in it.[17] Therefore, it is probable that Arfwedson's "silica" was really the beryllium hydroxide. He then precipitated the alumina by adding ammonium hydroxide to the acid filtrate. To satisfy himself of the purity of his alumina, he saturated the alkaline solution with hydrochloric acid until the precipitate dissolved, and added a large excess of ammonium carbonate. "Had any glucina [beryllia] or yttria existed in the matter," said Arfwedson, "it would have been dissolved by this excess of carbonate of ammonia, and would have fallen when the filtered liquid was boiled till the excess of ammonia was driven off; but the liquid stood this test without any precipitate appearing." Arfwedson was evidently unable to detect beryllia here because he had already filtered it off and reported it as silica.

In 1822 he published his famous paper on uranium.[18] More than thirty years before, Klaproth had heated a paste made with uranic oxide and linseed oil, and obtained a brown powder with a metallic luster, which he regarded as metallic uranium. Although others had used carbon crucibles in their attempts to reduce uranium oxide to the metal, Arfwedson used hydrogen. He placed a weighed portion of green "uranous oxide" [uranosic oxide], previously ground and ignited, in a bulb blown out at the center of a piece of barometer tubing, drove off the moisture, and passed dry hydrogen over it. As soon as the air had been removed, he heated the bulb with an Argand spirit lamp. A vigorous reaction took place, and in a few minutes the green "uranous oxide" had been changed to "a powder of a liver-brown color," which Arfwedson believed to be uranium metal.

He also prepared the "potash muriate of uranium" [potassium uranyl chloride, $K_2(UO_2)Cl_4$], and attempted to analyze it by reduction with hydrogen just as Berzelius had analyzed potassium chlorplatinate.[19] As Arfwedson passed hydrogen over the strongly heated salt, it continued to lose hydrochloric acid for more than two hours. After cooling the apparatus, he washed out the potassium chloride and the undecomposed salt and obtained a dark, crystalline powder with a metallic luster. When this was heated, it became converted into green "uranous oxide" [uranosic oxide]. During this change, 100 parts of the so-called "metal" [uranous oxide] gained 3.7 parts of oxygen. This was evidently the reaction: $3UO_2 + O_2 = U_3O_8$, in which 100 parts of uranous oxide actually gain 3.95 parts of oxygen; 100 parts of true uranium metal would have gained 17.9 parts of oxygen. Arfwedson, however, did not believe that his powder could be an oxide, for, according to Sir Humphry Davy's new theory regarding the composition of muriatic [hydrochloric] acid, the double chloride of uranium and potassium contained no oxygen.

Although Arfwedson, Klaproth, Berzelius, and many other eminent chemists long regarded this crystalline powder as the metal, E. M. Péligot in 1841 obtained the

[13] ARFWEDSON, "Undersökning af några mineralier," *Kongl. Vet. Acad. Handl.*, **1821**, pp. 147–55.

[14] ARFWEDSON, "Undersökning af några mineralier," *ibid.*, **1822**, pp. 87–94; *Annals of Philos.*, **23**, 343–8 (May, 1824).

[15] THOMSON, THOMAS, "History of chemistry," Colburn and Bentley, London, **1831**, vol. 2, p. 229.

[16] VAUQUELIN, "Analyse de l'aigue marine, ou béril, et découverte d'une terre nouvelle dans cette pierre," *Ann. chim. phys.*, [1], **26**, 155–77 (May (30 Floréal), 1798).

[17] F. HABER AND G. VAN OORDT, "Über Berylliumverbindungen," *Z. anorg. Chem.*, **38**, 380–1, 397 (Feb. 17, 1904)

[18] ARFWEDSON, "Bidrag till en närmare kännedom om uranium," *Kongl. Vet. Acad. Handl.*, **1822**, pp. 404–26; *Annals of Philos.*, **23**, 253–67 (April, 1824).

[19] BERZELIUS, "Note sur la composition des oxides du platine et de l'or," *Ann. chim. phys.*, (2), **18**, 149–50 (1821).

true metal. When he heated uranous oxide with carbon in a current of chlorine, he obtained carbon monoxide, carbon dioxide, and a green crystalline compound which is now known to be uranous chloride, UCl_4. Since the evolution of carbon dioxide and carbon monoxide showed that the so-called "uranium" must contain oxygen, Péligot heated the uranous chloride with potassium and succeeded for the first time in preparing and studying true metallic uranium.

When Arfwedson tried to analyze lead uranate by reducing it with hydrogen, it gained weight and became hot. When he placed the reduced mass on paper, he was astonished to see it burst into flame. He also prepared other pyrophoric alloys of uranium in the same way. "The uranium alloys," said he, "absorb oxygen again at ordinary temperatures, become ignited, and thus constitute a peculiar kind of pyrophors which are not inferior in flammability to those already known."

In 1822 Arfwedson published a paper on the decomposition of sulfates with dry hydrogen.[20] In the following year the British mineralogist H. J. Brooke (1771–1857) described a new mineral, *arfwedsonite*.[21] "The benefits which mineralogy has derived from the labours of Mr. Arfwedson," said he, "have induced me to associate his name with this mineral, which is from Greenland, and is black and foliated, and has been hitherto called ferriferous hornblende . . ."

In the autumn of 1824 Arfwedson helped Berzelius and Wilhelm Hisinger arrange the mineral collection of the Academy of Sciences according to Berzelius' chemical system. Two years later Berzelius visited Arfwedson at Hedensö. "This," said he, "is a most beautiful place, and Arfwedson and his wife have improved it since I was here last time. Inside there reigns extreme neatness and a degree of luxury which could be much less and still be sufficient."[3,*] Berzelius' pleasure was marred, however, by an attack of gout which did not yield even when Arfwedson himself applied nine leeches to the affected knee.

Although Arfwedson's business interests more and more distracted his attention from chemical research, this was not caused by the love of money. When one of his uncles bequeathed him the magnificent Forssby estate with its precious collection of oil paintings, Arfwedson allowed this inheritance to be shared according to law with the other heirs.

In the last year of his life, the Swedish Academy of Sciences awarded him its large gold medal[2] in honor of his discovery of lithium. He died at Hedensö on October 28, 1841, and was survived by his wife and three sons. The *Vetenskapsacademiens Handlingar* for that year contained the following tribute to his memory. "His love of order gave an impress of neatness not only to his person but also to everything about him. He had a pleasant manner; when different points of view were exchanged, he expressed himself with a deliberateness which was not compliance and with a thoroughness which showed deep thought. One may venture to say that, because he was obliged to devote his time to the management of a considerable fortune, . . . the science to which he devoted himself in his youth lost much."[4]

In conclusion we wish to thank Mr. Carl Björkbom of the Royal Library at Stockholm and Miss Amy Wästfelt of Upsala for their kind assistance.

[20] ARFWEDSON, "Om svafvelsyrade metallsalters sönderdelning med vätgas," *Kongl. Vet. Acad. Handl.*, **1822**, pp. 427–49; *Annals of Philos.*, **23**, 329–43 (May, 1824).

[21] H. J. BROOKE, "A description of the crystalline form of some new minerals," *Annals of Philos.*, **21**, 381–4 (May, 1823).

* Letter of Berzelius to Carl Palmstedt, July 26, 1826.

KEKULÉ ALBUM

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August Kekulé (1829–1896), the creator of the valence—or structural—chemistry and the formula of benzene and pyridine, was a great collector. He collected and classified butterflies and minerals. He made many friends, especially in his younger years. He kept their photographs in an album. This album was given by his son, Stephan, to the Kekulé Room of the Technical University of Darmstadt (see JOURNAL OF CHEMICAL EDUCATION, Volume 6, 1869 (1929)). It contains more than ninety photographs. Some of these photographs have been published in the classical biography of August Kekulé, written by his late successor, Richard Anschütz. Other photographs have not been published up to this time. The writer is happy to publish these at the suggestion of Professor Tenney Davis. Several of these pictures show the scientists at the time when they were performing their great achievements.

The CALCULATION *of the* LIMITING RESULTS OBTAINABLE *by* EXTRACTION *with* PARTIALLY MISCIBLE SOLVENTS

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CONSIDERABLE information exists on the maximum results to be expected in extraction processes employing immiscible solvents, including some computations on the economical and practical use of solvents in cases where the ordinary partition law holds.[1] It is of interest to examine the corresponding situations for partially miscible solvents, and also to indicate what practical results may be expected in the use of immiscible solvents when the ordinary partition law does not hold. In the following, graphical methods are presented for calculating the limiting solute removal possible in ternary systems of the usual type by multiple extraction when the solvent is used in infinitesimal portions, and by countercurrent extraction with an infinite number of perfect plates. It is oftentimes desirable to make such calculations in practice, since they show the limits of the process, somewhat similar to the degree of separation achievable in a distillation by differential evaporation or by use of a column containing an infinite number of plates.

Multiple extraction will be considered first. In this method of operation the solution to be extracted is contacted with successive fresh portions of the extracting solvent, each extract being removed before the next batch of fresh solvent is added. This is the usual procedure employed in laboratory scale extractions. In Figure 1 a typical ternary diagram is shown, with tie lines indicated by the broken lines.[2] Let the points on the left-hand side of the curve be denoted by (x,y,z) and the corresponding conjugate points on the right-hand side by (X,Y,Z), where x,y,z are the fractions of A,C,B, respectively, in the solution considered, and X,Y,Z the corresponding values for the phase in equilibrium with the solution. The solution to be extracted may be assumed in this case to lie on the equilibrium curve, since if it does not the fresh solvent added will keep dissolving until the resulting solution does lie on the curve, at which point phase separation and extraction will start. For the efficient use of a given amount of solvent in multiple extraction the solvent ordinarily should be used in successive small portions, and the limiting extraction approached as the subdivisions become smaller and smaller represents, in general, the maximum solute extraction possible by this method. This limiting value may be determined by the following method of Varteressian and Fenske.[3]

Suppose L grams of solution whose composition is given by a point (x,y,z) on the curve of Figure 1 are extracted with dm grams of pure solvent B. Then $L + dL$ grams of solution of composition $(x + dx, y + dy, z + dz)$ result, and dU grams of extract of composition $(X + dX, Y + dY, Z + dZ)$, these two compositions representing conjugate phases. The material balance equations for this process are

$$dL + dU - dm = 0 \qquad (1)$$

$$xdL + Ldx + XdU = d(xL) + XdU = 0 \qquad (2)$$

$$ydL + Ldy + YdU = d(yL) + YdU = 0 \qquad (3)$$

Assume an initial solution of L_1 grams of composition (x_1, y_1, z_1) is extracted in this manner with a total (to be determined) of M grams of solvent B, so that the final solution consists of L_2 grams of composition (x_2, y_2, z_2). The problem then consists in determining M and L_2, with L_1, (x_1, y_1, z_1), (x_2, y_2, z_2), and the equilibrium diagram being given. This requires the integration of the material balance equations between appropriate limits.

By eliminating dU between (2) and (3) and integrating one obtains

$$\int_{x_1,\ y_1}^{x_2,\ y_2} \frac{Xdy - Ydx}{xY - Xy} = \log_e \frac{L_2}{L_1}$$

The integral involved in the foregoing expression is a line integral taken along the equilibrium curve between the points (x_1, y_1) and (x_2, y_2), and, when the curve is known it may be evaluated graphically. This serves to fix the value of L_2 associated with any point (x_2, y_2, z_2) and vice versa. Now by using L and (x, y) as upper limits of integration in place of L_2 and (x_2, y_2) a functional relation is established between L and (x, y) throughout the extraction process, and this relation

[1] EVANS, *Ind. Eng. Chem.*, **26**, 439, 860 (1934); J. CHEM. EDUC., **13**, 536 (1936).

[2] OTHMER, *Chem. Met. Eng.*, **43**, 327 (1936).

[3] VARTERESSIAN AND FENSKE, *Ind. Eng. Chem.*, **28**, 1353 (1936).

may be substituted in the original material balance equations. In this way equation (2) yields

$$-U = \int_{x_1L_1}^{x_2L_2} \frac{d(xL)}{X},$$

so that by plotting values of $\frac{1}{X}$ against the corresponding values of xL and integrating graphically the value of U (total amount of extract layer formed) is determined. The value of M is then determined from the overall material balance $M = U + L_2 - L_1$. In a similar manner, had M been given initially and (x_2, y_2, z_2) been unknown the value of the latter could be secured. In case the solvent used is not pure B, but of the composition (X_0, Y_0, Z_0), then a term $-X_0dm$ must be added to equation (2), and $-Y_0dm$ to (3). The new integrals thus introduced may be evaluated graphically as before, although the work is still more tedious. It might also be noted for multiple extraction that on combining the separate extracts phase separation can occur, since in some cases the resulting overall composition will lie in the immiscible region. This latter point, however, is of theoretical rather than practical interest.

From a laboratory standpoint, the most interesting consideration is the amount of solvent required to achieve a certain degree of extraction, and the determination of a practical number of subdivisions in which the solvent should be used. Each specific case can be handled separately as above, but, since ternary systems vary widely in their properties, no exact generalizations can be drawn applicable to every system. By restricting the problem to systems in which the solvents can be considered immiscible, the variables involved are reduced considerably, and by examining the results obtained with various partition laws certain useful conclusions may be drawn. These conclusions can then be checked to a degree by considering specific ternary systems. It has already been shown[1] when the ordinary partition law holds that by subdividing the solvent into five portions at least 94 per cent. of the solute removal possible by infinite subdivision is achieved, so that five subdivisions represent a satisfactory practical figure for this case. The percentage of the initial solute removed also happens to be independent of the initial solute concentration for this case, depending only on the partition coefficient and the relative volume of solvent used. If, however, the ordinary partition law is not obeyed, then the percentage solute removal obtainable depends on the initial solute concentration as well as other factors.

For simplification of the equations in the immiscible case, let x denote the solute concentration in the extracting solvent, y the concentration in the solution, the units being grams solute per gram of solute free solvent, x and y being in equilibrium. Let L equal the grams solution to be extracted (on a solute-free basis), and U the grams extracting solvent to be employed. Then for the following equilibrium relationships we have the corresponding fractions of the solute removed (y_1 and y_2 are initial and final solute concentrations), the extracting solvent being used in infinitesimal subdivisions[1]

$$y = k\sqrt{x}, \quad \frac{y_1 - y_2}{y_1} = \frac{\frac{y_1U}{k^2L}}{1 + \frac{y_1U}{k^2L}}$$

$$y = kx, \quad \frac{y_1 - y_2}{y_1} = 1 - e^{-\frac{U}{kL}}$$

$$y = kx^2, \quad \frac{y_1 - y_2}{y_1} = \frac{U}{L\sqrt{ky_1}}\left(1 - \frac{1}{4}\frac{U}{L\sqrt{ky_1}}\right)$$

This variation in equilibrium equations is sufficient to embrace most of the situations encountered in practice. It is apparent that depending on the form of the equilibrium relationship the fraction of the solute removed is a function of

$$\frac{y_1U}{k^2L^2}, \quad \frac{U}{kL^2}, \text{ or } \quad \frac{U}{L\sqrt{ky_1}}$$

On the other hand, if the extracting solvent is divided into a finite instead of an infinite number of equal portions, (say n portions), then the fraction of solute removed also can be shown to depend on these same groups of variables. Consequently, by tabulating percentage solute removed as a function of these groups of variables for several finite values of n and also for $n = \infty$, a general view of the problem of multiple extraction is had. These data are given in Tables 1, 2, and 3. [Table 2 has been given previously.[1]] The final column of each table is the fraction of solute removed by division of the solute into five equal portions divided by the fraction removed on infinite subdivision. This column consequently gives the relative efficiency secured by five subdivisions, regarding infinite subdivision as giving 100 per cent. efficient use of the given amount of solvent. From these tables it is seen that five subdivisions of the solvent gives in every case over 90 per cent. as much solute removal as does infinite subdivision. Consequently, in practice, it is usually not worth while to use the solvent in more than five portions, the slight gain in efficiency achieved by further subdivision being more than offset by the increased labor. In passing it might be noted that the above equations for infinite subdivision correspond closely to the situation prevailing in a continuous laboratory extractor of the common type in which the solvent passes through the solution to be extracted and flows into a flask where the solvent is flashed off and recirculated through the solution. A correction term may be added to compensate for the constant amount of solvent held up in the extractor, but since this hold-up is normally small in comparison to the total amount of solvent circulated, these correction terms are ordinarily of little importance.

Returning to systems in which mutual solubilities of the solvents must be taken into account we may examine the system chloroform–water–acetic acid shown in Figure 1. At low acid concentrations the system

approximates to the distribution of acetic acid between two immiscible solvents and hence the results obtained in this region will conform to those deduced for immiscible systems. At high acid concentrations departures from this behavior might be expected. To investigate this point, let 100 parts of a solution of composition 50 per cent. acetic acid, 35 per cent. water, 15 per cent. chloroform be extracted with chloroform to a composition of 30 per cent. acid, 68 per cent. water, 2 per cent. chloroform, the extracting agent being used in infinitesimal portions. Upon performing the computations, it is found that approximately 165 parts of chloroform are required and that 43 parts of extracted solution are obtained. By using 165 parts of chloroform in five equal subdivisions, calculations indicate that 46 parts of extracted solution of the composition 33 per cent. acid, 64 per cent. water would be obtained. These computations were all made from ordinary size graphs and hence subject to some uncertainties. However, they do make plausible the conclusion that in general five subdivisions of the solvent represent a practical working figure.

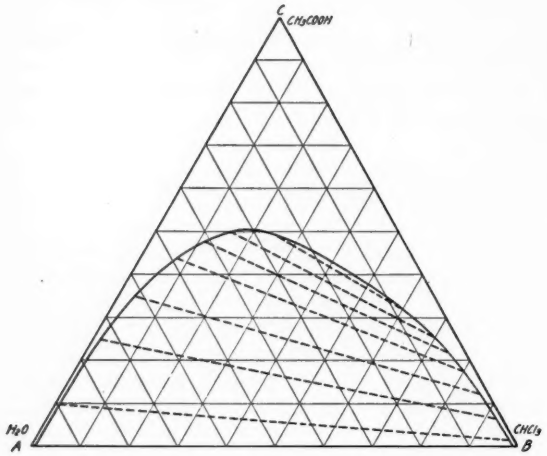

FIGURE 1.—THE TERNARY SYSTEM CHLOROFORM–ACETIC ACID–WATER

Coming to countercurrent extraction, some confusion exists as to the results obtainable with given feeds, assuming an extraction column equivalent to an infinite number of perfect plates is available. In this case the solution to be extracted enters one end of the column, the fresh solvent the other end, and the two liquids pass each other countercurrently. The extracted solution then leaves where the fresh solvent enters, while the extract leaves where the solution enters. It might be inferred[3] that for an infinitely long tower the extract leaving the tower is at equilibrium with the entering feed composition if the feed composition lies on the binodal curve; otherwise that it is in equilibrium with the solution which would be obtained by adding solvent directly to the incoming feed until the resulting mixture was on the verge of splitting into two phases. However, neither of these conceptions is necessarily true. On the contrary, as will be shown, the composition of the extract leaving such a tower depends on the nature of the binodal curve, the composition of the feed, the ratio of solvent to solution, and the slopes of the tie lines. Since these are calculations which are frequently useful and easily made, they will be described in detail.

Let the ternary system in question be of the type shown in Figure 2. Let the incoming solution correspond in composition to the point D, and let it be extracted countercurrently with pure solvent B. For a fixed ratio of solvent to feed, say $m_1 : m_2$, the point E representing the overall composition of the sum of the two feeds lies on the line DB and $DE : EB = m_1 : m_2$. Since the sum of the materials entering the column must equal the sum of the materials leaving, the compositions of the extract and extracted solution must be represented by points on the binodal curve lying on a line through E. The problem is to determine this line through E which will give the compositions of the exit solution and extract, assuming the tower has an infinite number of perfect plates. This is most easily accomplished by recalling the method[1] used to determine the composition of the resulting solutions when using a finite number of plates, and then noting what happens as the number of plates becomes infinite.

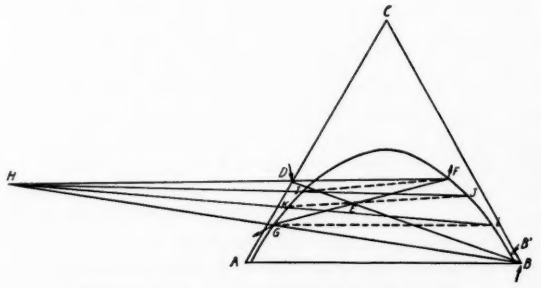

FIGURE 2.—COUNTERCURRENT EXTRACTION

Assume F and G represent the extract and extracted solution, respectively. Then point H is located as the intersection of DF and GB. Now if F represents the extract flowing from the top plate of the column, the solution layer on this plate must be given by the other extremity of the tie line through F, since the plates are assumed perfect, *i.e.*, equilibrium exists between the phases in each plate. Call this point I, the tie line being drawn as a broken line. Then the composition of the extract layer on the next plate down is found by drawing the line HI and thus securing the point J. The solution layer in equilibrium on this plate is given

by the tie line through J, giving the point K. The extract layer on the next plate below this is secured as before by drawing the line HK and thus securing L, and the solution layer on this plate by the tie line through L. As drawn here this tie line passes through G, which was the assumed composition of the extracted solution leaving the tower. Hence for this situation three plates were sufficient to reach the assumed exit concentrations. Now in examining the steps pursued to determine the change in composition from plate to plate it is apparent that the construction could have started from the point G equally as well as from F, and the calculations made up the diagram rather than down. In either case it is seen that for the construction to proceed each tie line encountered must bear a definite relation to the point H. In particular, for the situation pictured, each tie line must, if prolonged, pass below the point H. Otherwise it is impossible to advance from the point F to the point G, for the geometric construction proceeds in the wrong direction. Consequently, if all the tie lines in the interval considered do pass below H, then the assumed exit concentrations can be reached with a finite number of plates (but not necessarily an integral number—*e. g.*, there may be required more than four but less than five). If one of the tie lines passes above H, then the assumed exit concentrations cannot be reached by this type of extraction process with the given feed ratio. But if one (or more) of the tie lines passes through H, while the remainder pass below H, then the assumed exit concentrations can be reached, but only by use of an infinite number of plates. This follows since the geometric construction always proceeds in the proper direction, but, as the tie line through H is approached, the concentration change from plate to plate becomes smaller and smaller and an infinite number of lines or plates are required to reach this concentration. The tie line through H may be the tie line at an end of the construction, or it may be one of the interior lines. The above restriction that the tie lines pass below H also depends on the location of H; if conditions had been such that H lay on the solvent instead of the solution side of the diagram then the requirement would be reversed as is easily seen on drawing the figure.

From the foregoing, it is evident that a somewhat empirical procedure must be employed in determining the performance of an infinite column, since the behavior of all the tie lines must be considered, and each change in assumed exit concentrations shifts the reference point H and hence the geometric construction. A limiting extract often corresponds to the tie line which when prolonged passes through the feed composition. However, whether this extract actually can be obtained depends upon the ratio of the feeds and the remainder of the ternary diagram, and can be determined only by inspection of the system. Hence, in practice, such an exit concentration F can be assumed, the point H located, and a few lines drawn to determine whether the rest of the construction is feasible. If it is not feasible, then a poorer extract must be assumed and the process repeated until the limiting case is reached. In some instances it may be preferable to assume the composition of the exit solution G rather than the extract F, a limiting value for this composition often corresponding to the tie line passing through the point representing the solvent employed. As indicated above, however, since E is known the choice of F determines G and vice versa, so that it is merely a matter of convenience as to which is assumed. If the feed composition D lies above all the tie lines the foregoing general considerations still apply, and the situation can be handled similarly. This case can display certain peculiarities, as extraction may not be feasible because all possible mixtures of feed and solvent are homogeneous, or the liquid on the top plate of the column may be homogeneous. Another unusual case is conceivable in that more than one tie line may pass through the feed or extracting solvent composition, thus requiring somewhat closer examination to determine the limiting conditions. These points are easily recognized and handled when encountered, and require no special discussion.

The foregoing discussion has assumed that the feed ratio is fixed and the exit concentrations are desired.

TABLE 1

PERCENTAGE OF SOLUTE REMOVED FOR A PARTITION LAW OF THE FORM $y = k\sqrt{x}$

$\frac{y_1 U}{k^2 L}$	Number of Subdivisions 1	2	5	∞	$\frac{n = 5}{n = \infty}$
2.5	54	61	67	71.5	0.94
7.5	70	78	84	88.2	0.95
12.5	75	84	89	92.5	0.96
25	82	89	94	96.2	0.98
50	87	93	97	98.0	0.99

TABLE 2

PERCENTAGE OF SOLUTE REMOVED FOR A PARTITION LAW OF THE FORM $y = kx$

$\frac{U}{kL}$	Number of Subdivisions 1	2	5	∞	$\frac{n = 5}{n = \infty}$
1	50	56	60	63.2	0.95
2	67	75	81	86.5	0.94
3	75	84	90	95.0	0.95
5	83	92	97	99.3	0.97
10	91	97	99	99.9	0.99

TABLE 3

PERCENTAGE OF SOLUTE REMOVED FOR A PARTITION LAW OF THE FORM $y = kx^2$

$\frac{U}{L\sqrt{k y_1}}$	Number of Subdivisions 1	2	5	∞	$\frac{n = 5}{n = \infty}$
0.5	39	41	43	43.7	0.99
1.0	62	68	75	75.0	0.96
1.2	68	75	80	84.0	0.96
1.5	75	83	89	93.6	0.95
2.0	83	91	97	100	0.97
3.0	91	98	99.8	100	0.99

However, it is often desired to calculate the feed ratio necessary to reach a fixed exit concentration in an infinite column, the entering solution composition being given. In this case the points D and G are given and it is desired to locate E, since the ratio of the feeds is given by $DE : EB$. This is accomplished by assuming different values for F and observing, as above, which value demands an infinite number of steps in the extraction. While Figure 2 shows that pure solvent B is used for the extraction this is not necessary to the theory; if a solvent mixture had been used corresponding to the point B', for example, then line BG would be replaced by $B'G$, etc. Also, the point H can vary widely in location depending on the situation involved, so that Figure 2 should be taken as illustrative only.

It should be realized that in the partially miscible systems all three components are usually present in both the extract and the extracted solution. Consequently, in judging the desirability of one form of operation as compared with another, attention must be paid to the compositions and relative masses of the final solutions obtained from the extraction step, and also to the products obtained when these solutions are freed from their contained solvent.[3] Since the ease of solvent removal and the proportion of the other constituents removed with the solvent vary with the system, each problem demands more or less individual treatment in this respect. In some cases it may be desirable to return a portion of the solvent-freed extract to the extraction column, either blending it with the feed or introducing the feed at a suitable intermediate point in the tower. This has the effect of providing a richer feed to the column and generally can be arranged to yield a richer extract. Here again, however, each system must be considered individually to decide whether such modification is desirable.

CHEMICAL HYDRATION NUMBERS

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THE effect commonly termed chemical hydration is caused by specific force interactions between the solute and the dipolar solvent, with the result that a number of water molecules orient themselves around each solute molecule, forming a complex aquo-ion.†

Ulich (*1*) has calculated the chemical hydration numbers of a series of ions by an entropy deficiency method. The results are shown in Table 1, which has been partly revised and enlarged by the author, using the recent entropy values of aqueous ions given by Latimer (*2*), together with those of gaseous ions recommended by Kelley (*3*). It is worth noting that the corrected hydration numbers for Mg^{++} and Ca^{++} are in still better accordance with the values calculated from conductance data than are those reported by Ulich. Hydration numbers of mercuric, hydroxyl (*4*), and ferric ions have also been calculated and included in Table 1.

TABLE 1

HYDRATION NUMBERS OF IONS IN WATER AT 25°

Ion	H^+	Li^+	Na^+	K^+	Rb^+	Ag^+	Tl^+	F^-	Cl^-	Br^-	J^-	OH^-	S^{--}
n	4	5	3½	2	2	3½	2	5	2	1½	½	7	4

Ion	Mg^{++}	Ca^{++}	Ba^{++}	Zn^{++}	Cd^{++}	Hg^{++}	Cu^{++}	Fe^{++}	Sn^{++}	Pb^{++}	Hg_2^{++}	Fe^{+++}	Al^{+++}
n	12	8½	7	11	9	8½	10½	11	8	7	7	18	19

* Research chemist.

† Compare for instance N. F. HALL, *Chem. Rev.*, **19**, 89 (1936), and several papers of H. BRINTZINGER, *Z. anorg. allgem. Chem.* (1934–36).

It must be pointed out, however, that the total entropy of hydration is an integrated effect upon all of the surrounding water molecules, and the assumption of a constant entropy deficiency per water molecule cannot be strictly justified. Accordingly the hydration numbers obtained by the method of Ulich must be regarded as mean stoichiometric ones only; but in many cases they may not the less be of some value, for example in connection with the problem of aquo-ions and other complex ions. The distinction between the chemical and the total hydration is emphasized by the following comparison:

	Source	Li^+	Na^+	F^-	Be^{2+}	Ca^{2+}	Al^{3+}	Fe^{3+}
Chemical hydration numbers	Author's Table	5	3½	5		8½	19	18
	H. Brintzinger	5	3		18	6	18	18
Total hydration numbers	H. Brintzinger	22	16	12½	87	33	86	90

Further, it would be of interest to obtain values of the hydration numbers also for non-electrolytes, polar ones as well as non-polar. The author has carried out such a calculation, based upon the entropies of hydration given by Butler and Reid (*5*). The decrease in entropy per gram-mole of water forming the hydrate was tentatively taken equal to 6 E.U. as suggested by Ulich (*1*). Accordingly, one obtains the hydration number by dividing the difference between the entropy of aqueous

ions and the corresponding gaseous ones by six. The results are given in Table 2.

TABLE 2

ENTROPIES OF HYDRATION AND HYDRATION NUMBERS OF SOME GASES AND ORGANIC COMPOUNDS IN WATER AT 25°

Substance	*Entropy of hydration* $-\Delta S$	*Hydration number* n	*Calcd. by additivity* n
Inert gases			
Helium	9	1½	
Neon	11	2	
Argon	14	2½	
Krypton	16	2½	
Xenon	17	3	
Radon	18	3	
Common gases			
Hydrogen	10	1½	
Nitrogen	13	2	
Oxygen	15	2½	
Carbon monoxide	13	2	
Carbon dioxide	14	2½	
Carbonyl sulfide	19	3	
Methane	16	2½	
Ethane	19	3	2
Ethylene	15	2½	2
Acetylene	9	1½	2
Methyl chloride	17	3	2
Aliphatic alcohols			
Methyl	19	3	3
Ethyl	25	4	4
n-Propyl	31	5	5
i-Propyl	27	4½	4½
n-Butyl	36	6	6
i-Butyl	34	5½	5½
sec.-Butyl	34	5½	5½
tert.-Butyl	32	5½	5
n-Amyl	42	7	7
tert.-Amyl	36	6	6
Other compounds			
Ethylamine	26	4	4
Ethyl acetate	27	4½	4
Acetone	19	3	3
Glycerol	51	8½	9
Chloroform	28	4½	4

DISCUSSION

Perhaps the most striking feature, when examining the hydration numbers, is the fact that the degrees of hydration of these non-electrolytes seem to be quite as great as those of the common low-valent ionic species given in Table 1. Even the inert gases are hydrated, and to an extent corresponding to the least hydrated ions. The higher aliphatic alcohols have hydration numbers corresponding to the most hydrated monovalent ions, while glycerol must be compared with the divalent ones.

Since non-electrolytes, and even the inert gases, have been shown to be hydrated to a considerable extent, it is evident that the hydration effects must have their origin both in van der Waals forces as well as in dipole or multipole interactions.* Such forces one must also take into account in the case of electrolytes. Hence it is natural that many objections (*6*) have already been raised against the validity of the Born-Bjerrum equation for the heat of hydration of electrolytes, which takes into consideration electrostatic effects only. In their investigations concerning univalent organic electrolytes, McBain and Betz (*7*) have found that association, due to van der Waals cohesive forces, is so dominant that it completely submerges the ordinary features of interionic attraction.

It is also interesting to note that Kortüm (*8*), investigating the light absorption in aqueous solutions, has found salt effects which for non-electrolytes are of the same order of magnitude as those for electrolytes.† Kortüm (*8*) concluded that the van der Waals forces are most probably of greatest importance for solving the remaining problems concerning solutions of electrolytes.

ADDITIVITY OF HYDRATION NUMBERS

It may be of interest that the hydration numbers for aliphatic compounds given in Table 2 have proved to be approximately additive.‡ Using the following figures, which necessarily must be regarded as only preliminary ones,

Atomic group	—OH	—NH_2	=CO	—Cl	—CH_3	=CH_2	≡CH
Hydration number	2	2	1	1	1	1	½

one obtains the values recorded in Table 2 (last column) in good accordance with the hydration numbers actually found by the entropy deficiency method (first column).

SUMMARY

Hydration numbers of thirty-two gases and organic compounds in water have been calculated by the entropy deficiency method, and compared with those for ionic species. In the case of the organic compounds examined, approximate additivity has been shown, and some preliminary values for different atomic groups are suggested.

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* The existence of crystalline hydrates of the rare gases argon, krypton, and xenon have already (MOELWYN-HUGHES AND SHERMAN, *J. Chem. Soc.,* **1936,** 101) been attributed to the interaction of the dipole of the water molecule and the dipole which it induces in the normally non-polar atom. The non-existence of crystalline hydrates of helium and neon were attributed to the low polarizabilities of these atoms. With the entropy deficiency method, however, we are able to detect hydrates also for these gases.

† That constitutive influences in several cases seem to overcome the effect of the charge, have also been emphasized in other connections—for instance, by N. F. HALL, *Chem. Rev.,* **19,** 89 (1936), when discussing Werner's series of basic cations.

‡ Compare additivity of other thermodynamic properties of organic compounds, for example, by PARKS AND HUFFMAN, "The free energies of some organic compounds," A. C. S. Monograph No. 60, The Chemical Catalog Co., New York City, **1932;** PARKS, *Chem. Reviews,* **18,** 325 (1936).

MAGNETISM *and* CHEMICAL CONSTITUTION

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IT HAS been a little over a century since Oersted and Ampère first pointed out that magnetism is a property of electricity in motion. Every electrical current has associated with it magnetic forces, and every closed electrical circuit is equivalent to a magnet of definite moment. Ampère suggested that a substance like iron owes its magnetic properties to a continuous circulation of electricity in each of its molecules, and that the magnetization of iron consists in the orientation of these electrical circuits in the same direction.

According to the Bohr theory of atomic structure, every atom contains electrical charges in rapid motion. This clarifies the origin of the magnetic properties of matter. So far, however, no entirely satisfactory explanation has been evolved to account for all the known facts of magnetism.

In 1845, in the course of investigation on the relation between magnetism and light, Faraday discovered that magnetic properties are not confined to the iron group of elements, but that *all* substances are weakly magnetic in character. He showed that substances can be divided into two classes depending on their behavior in a magnetic field. Those substances which tend to set their longer axes parallel to the field, like iron, were designated as paramagnetic and those which tend to set themselves transversely in the field, diamagnetic.

Paramagnetism is divided into two sub-classes—paramagnetism proper and ferromagnetism. Ferromagnetism is distinguished from paramagnetism proper by the exhibition of forces of much greater magnitude and by the occurrence of a lag in the relation between the magnetic state of the substance and that of the field. In the studies of magnetism this particular lag is known as hysteresis. Ferromagnetism is confined as far as we know to date, to a very few elements, namely those of the iron group and to a very limited number of compounds, *e. g.*, magnetic oxide of iron, Fe_3O_4. Both ferromagnetism and paramagnetism proper are unquestionably the result of an atomic property, but they differ in that the stronger ferromagnetism is definitely confined to substances in the solid state and is dependent upon the crystal structure.

On the other hand, most other substances exhibit the much weaker, but characteristic dia- or paramagnetism no matter what the state of aggregation. It is, therefore, concluded that these are entirely independent of physical state or crystalline form. The fundamental laws of these phenomena were established by P. Curie, who showed that diamagnetic susceptibility is independent of temperature, whereas the paramagnetic susceptibility of a substance varies inversely as the absolute temperature or

$$XT = K$$

where X is the susceptibility, T, the absolute temperature and K a characteristic constant. The susceptibility X is the ratio of the degree to which the substance becomes magnetized and the strength of the magnetic field into which the substance is introduced.

THE ORIGIN OF ATOMIC MAGNETISM

Every rotating or revolving electron in an atom, being a current of electricity, will have a magnetic moment; that is, it will act as a micro-magnet. It is entirely conceivable that these electrons might be so located with respect to one another that the effects of one tiny magnet might neutralize those of another. A simple instance of such an arrangement would be afforded by an even number of symmetrically arranged electronic shells in half of which the electrons are moving clockwise, the other half counter-clockwise. On the whole, the atom would possess in such a case no magnetic moment. However, experiment shows that external magnetic fields modify the electronic energy levels (*e. g.*, Zeeman effect of spectroscopy). One might, therefore, expect the exhibition of *some* magnetism in the presence of a field. This is known as diamagnetism. Diamagnetism is common to all matter, whether it is masked by paramagnetism or not. It is independent of temperature and the state of aggregation of the substance.

If the electrons of an atom are of uneven number or if they are so arranged that their magnetic moments are not all completely neutralized by those of others, then the atom will exhibit paramagnetism. In other words, the exhibition of paramagnetism by an atom or ion indicates a lack of symmetry and of magnetic balance in the electronic orbits. From the magnetic point of view the salts of the transition elements (*e. g.*, the salts of vanadium, chromium, manganese, iron, cobalt, and nickel) are of particular interest owing to their paramagnetic characteristics (see Table 1).

In the formation of a diamagnetic, polar compound there is a gain or loss of electrons by the reacting atoms, the outer electrons of the ion tending to assume an in-

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ert gas configuration. In sodium chloride, to take a simple example, the sodium atom loses an electron, the chlorine gains one; the electronic constitution of these ions will be similar to those of the inert gases neon and argon, respectively, which possess complete and stable configurations. These complete configurations correspond to symmetrically balanced electromagnetic systems possessing no resultant magnetism and thus exhibiting only diamagnetism in the presence of a field.

The ions of the transition elements (see Table 2), on the other hand, possess electronic configurations of an incomplete sort, and the lack of magnetic balance gives the ion a resultant magnetic moment, and ionic paramagnetism results. Thus simple ions or atoms with complete configurations, as in the inert or pseudo-inert gas configurations, are diamagnetic; while those with incomplete configurations are paramagnetic.

TABLE 1

MAGNETISM OF SOME SIMPLE ATOMS AND IONS

Pseudo-Rare Gas Configuration			*Rare Gas Configuration*						*Non-Rare Gas Configuration*						
							He	←Li^{+}	Be^{++}	B^{+++}						
							C^{IV}	N^{III}	O$^{=}$	F^{-}	→**Ne**←	Na^{+}	Mg^{++}	Al^{+++}			
							Si^{IV}	P^{III}	S$^{=}$	Cl^{-}	→**A**←	K^{+}	Ca^{++}	Sc^{+++}	Ti^{++++}	V^{IV}	Cr^{+++}	Mn^{++}	Fe^{++}	Co^{++}	Ni^{++}
←Cu^{+}	Zn^{++}	Ga^{+++}					Ge^{IV}	As^{II}	Se$^{=}$	Br^{-}	→**Kr**←	Rb^{+}	Sr^{++}	Yt^{+++}	Zr^{++++}	Cb^{IV}	Mo^{VI}	43^{IV}	Ru^{III}	Rh^{+++}	Pd^{++}
←Ag^{+}	Cd^{++}	In^{+++}					Sn^{IV}	Sb^{II}	Te$^{=}$	I^{-}	→**Xe**←	Cs^{+}	Ba^{++}	La^{+++}*†	Hf^{++++}	Ta^{IV}	W^{VI}	Re^{IV}	Os^{III}	Ir^{+++}	Pt^{++++}
←Au^{+}	Hg^{++}	Tl^{+++}					Pb^{IV}	Bi^{II}	Po$^{=}$	85^{-}	→**Rn**←	87^{+}	Ra^{++}	Ac^{+++}	Th^{++++}	Pa^{IV}	U^{VI}				

† Also Lu^{+++}.

* Rare earth element ions excepting La^{+++} and Lu^{+++}

DIAMAGNETIC PARAMAGNETIC

TABLE 2

THE MAGNETIC SUSCEPTIBILITIES OF CERTAIN IONS AND INERT GASES AS A FUNCTION OF THEIR ELECTRONIC CONFIGURATIONS

Ion (Chloride) or Inert Gas	*No. of Electrons in Bohr Shells* K	L	M	N	*Paramagnetic Susceptibility per Gram-ion at Room Temperature × 10^{6} C. G. S. Units*
A	2	8	8	..	Diamagnetic
K^{+}	2	8	8	..	Diamagnetic
Ca^{++}	2	8	8	..	Diamagnetic
Sc^{+++}	2	8	8	..	Diamagnetic
Cr^{+++}	2	8	11	..	7000
Cr^{++}	2	8	12	..	10300
Mn^{++}	2	8	13	..	13500
Fe^{+++}	2	8	13	..	14000
Fe^{++}	2	8	14	..	13800
Co^{++}	2	8	15	..	11800
Ni^{++}	2	8	16	..	5800
Cu^{++}	2	8	17	..	1200
Cu^{+}	2	8	18	..	Diamagnetic
Zn^{++}	2	8	18	..	Diamagnetic
Kr	2	8	18	8	Diamagnetic

Paramagnetism is usually so pronounced that it completely overshadows the diamagnetic properties. Paramagnetic atoms tend to arrange themselves in an external magnetic field so that their magnetic axes are parallel to the field. This orientation is resisted by opposing forces—principally thermal agitation—so that unless the field is very powerful, the orientation is very imperfectly accomplished and the magnetization is far from the saturation value. This is virtually a restatement of Curie's law—the paramagnetic susceptibility varies inversely as the temperature.

It should be noted that neither diamagnetic nor paramagnetic substances exhibit their magnetic properties in the absence of an imposed field. In other words, they do not exhibit permanent magnetism so well known in the case of the ferromagnetic iron-group elements. Diamagnetic substances in the massive form are magnetically neutral in the absence of a magnetic field because of the magnetic compensation within the atoms themselves. Paramagnetic substances are neutral because of the counteraction of the magnetic moments of the constituent atoms as a result of the random orientation of the atoms.

THE METHODS OF MEASUREMENT OF MAGNETISM

Two different general methods of determination of the magnetism of substances have been employed. The first which is applied to substances *en masse* was first devised essentially by Faraday. The second is of more recent origin and makes use of the effect of a magnet upon a stream or pencil beam of atoms or molecules in a vacuum tube.

Soon after Faraday's discovery of the universal occurrence of magnetism and his differentiation of substances into dia- and paramagnetics, he made a large number of comparative measurements, using the method which goes by his name. The Faraday method as modified by Curie, as well as by Gouy, is based on the measurement of the force on a small specimen in a magnetic field just as one might measure the strength of a weak iron ferromagnet.

An explanation of the Gouy modification as illustrated in a simplified fashion in Figure 1-A will disclose the essential features of the method. A uniform cylinder of the substance A is suspended with one end in a homogeneous field between the poles of a magnet (M and M'), the other end in a region where the field is negligible. The force may be determined by direct weighing if a sensitive balance of special type is used. Obviously, the greater the magnetic susceptibility of the substance, the greater will be the force with which it is drawn into the field.

The absolute measurement of magnetic susceptibility is a difficult task, since the strength of the magnetic field must be determined and the effects of other factors must be known or kept constant. Just as in the measurement of densities and viscosities, the most practical

method is a relative one centering about the use of a standard substance. The magnetic susceptibility of manganese pyrophosphate, $Mn_2P_2O_7$, for example, has been determined with great care. Since this salt is easily obtainable in pure and well-defined form, it makes an excellent standard for the calibration of the magnetic susceptibility balance. Standard substances are available also in the gaseous and liquid states.

For liquids, Quincke has devised an ingenious method based on the same principle as Gouy's method. Essentially, a U-tube is employed, one arm being of wide, the other of narrow bore (Figure 1-B). The narrower tube passes between the poles of a magnet, the meniscus being where the field is uniform. When the field is applied the meniscus will rise or fall; the displacement is measured and compared with that of a standard solution. The magnitude of the usual displacement may be illustrated by the fact that for a concentrated solution of ferric chloride with a field of 20,000 gauss, the meniscus will be elevated several centimeters.

For gases, an elaborated Quincke apparatus has been employed in which the measurement of the difference of pressure produced between two points in a gas, one of which is in a magnetic field and the other outside the field, is made.

Some of the methods of measurement of ferromagnetic materials have been applied to strongly dia- or paramagnetic substances, but the range of such substances is very limited, although the method is very successful at very low temperatures* where the susceptibility of most paramagnetic substances is very high (Curie's law). The principle involved in the usual method is that of the simple electric transformer. One or two solenoids of wire (Figure 1-C) enclose the specimen of paramagnetic substance so that the substance acts as the core of a small electric transformer. When an alternating or interrupted current is sent through the primary coil, all other conditions being constant, the voltage induced in the secondary coil will depend upon the magnetic susceptibility (permeability) of the core. Thus the voltage of the secondary circuit is a direct measure of the magnetic susceptibility of the substance. Sometimes a single coil is used, in which case the change in self-inductance of the coil, when the substance under investigation is substituted for air as the core, is a measure of the susceptibility of the core.

In deducing paramagnetic moments, corrections have to be made for diamagnetic effects. In solutions, the susceptibility of the solvent must be taken into account. To obtain the value for a particular paramagnetic ion, say the nickelous ion, Ni^{++} in nickel sulfate, it is necessary to correct for the diamagnetism of the sulfate ion, as well as for the diamagnetism of water of hydration, if present. The corrections can be made with sufficient accuracy by use of a table of values derived by Pascal for the diamagnetic susceptibility per gram-ion or gram-mole. A brief list of Pascal's values is given in Table 3.

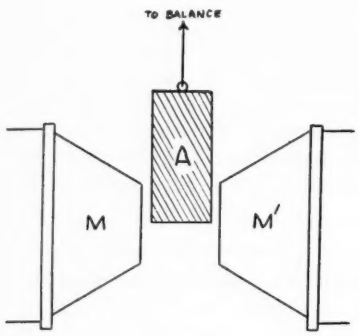


FIGURE 1-A

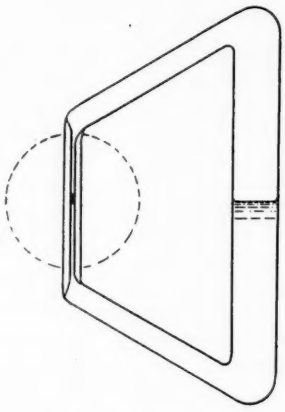


FIGURE 1-B

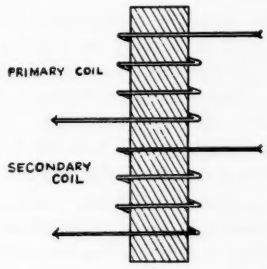


FIGURE 1-C

APPARATUS EMPLOYED IN THE DETERMINATION OF MAGNETIC SUSCEPTIBILITY

The corrections are comparatively small for most paramagnetic substances, the gram-molecular susceptibility of nickelous chloride, $NiCl_2$, *e. g.*, amounting to the order of 5000 susceptibility units at ordinary temperatures, the diamagnetic correction being 40 units.

It was pointed out earlier that even paramagnetic substances possess an underlying diamagnetism, which is usually masked. The correction for such an effect cannot be determined by any known method to date. However, plausible estimates for the nickelous ion, for instance, give the correction a value of the order of 0.1 per cent.

MAGNETISM OF ATOMIC RAYS

Magnetic measurements on atomic rays (Stern and Gerlach, beginning 1921) are made under conditions

* Paramagnetic salts have been used extensively recently in the production and measurement of temperatures below 1° Absolute. The essential features of this method have been described by L. L. QUILL AND R. F. ROBEY, *School Sci. and Math.*, **36**, 871 (1936).

quite different from those of any other magnetic measurement. In the experiments the element under investigation is heated in a small furnace (*A*, Figure 2),

TABLE 3

DIAMAGNETISM OF CERTAIN IONS AND MOLECULES

Ion	$\chi_{molar} \times 10^6$ *C.G.S. Units*	*Ion*	$\chi_{molar} \times 10^6$ *C.G.S. Units*
F^-	11.5	$SO_4^=$	37
Cl^-	20	NO_3^-	18
Br^-	31	NH_3	14
I^-	45	H_2O	13
CN^-	11	Na^+	3.8
		K^+	10.6

and the evaporating atoms escape at a velocity calculated from the kinetic theory of gases through an aperture *B* into a highly evacuated chamber. The stream of metallic vapor issuing from the hole in the furnace wall passes through two parallel slits *C* and *C'* so as to reduce it to a narrow beam of atoms. The stream continues between the poles of a powerful electromagnet *D* offering an inhomogeneous field; and finally the beam is permitted to impinge on a glass plate *E* forming a thin deposit. From the traces on the glass obtained with and without the field, the deviation produced by the field may be determined.

Although the experimental difficulties are great, Stern and Gerlach accomplished the measurement of the magnetic moment of practically isolated atoms entirely removed from the influences of surrounding atoms. The discovery of new atomic magnetic phenomena, which are masked by atomic interaction in the magnetic measurements *en masse*, was to be expected.

That which is observed with silver atoms is a splitting of the beam into two images or traces of equal proportions and intensity. This is possible only if atomic magnets are oriented in two ways—half of them having their magnetic axes parallel and half anti-parallel to the imposed magnetic field. The experiment shows that an isolated neutral silver atom has a definite magnetic moment, and the direction of the deviation of a silver atom in a beam of atoms depends entirely upon the orientation of this moment. From the separation of the two beams the actual magnitude of this moment has been calculated and the value found to be equal to 5589 ergs per gauss per gram atom.

The application of this method to other metals has led to some very interesting results although the work has not yet been carried very far. It is very interesting that the first-group metals copper, gold, sodium, and potassium give rise to the same beam phenomenon as silver and that the atomic beam deviation is of the same magnitude.

It has already been stated that atoms with a stable or complete electronic configuration are diamagnetic, having no resultant magnetic moment. The copper family and the alkali family metals possess one electron in excess of a completed configuration located in the outermost or valence shell. In all probability it is in this shell that the magnetism arises. Curiously, the magnetic moments of other atomic species have been found *to be equal to* or exact *multiples of* those of the first periodic group. We thus have direct evidence of the existence of an elementary and fundamental unit of magnetic moment, known commonly as *the magneton.*

THE MAGNETON

In the course of his investigations on ferromagnetics, Weiss came to the conclusion (1911) that the magnetic values obtained by him were all integral multiples of a unit of magnetic moment—the Weiss magneton, the value of which is 1126 ergs per gauss per gram-atom. The Weiss magneton has been of great convenience for the expression of deduced atomic moments. However, it is by no means a fundamental unit, as would scarcely be expected, in view of the large number of magnetons (up to fifty) which must be assumed for some atoms. Furthermore, it has not been possible to derive the Weiss magneton from the known atomic constants.

The basis of the present-day outlook upon the quantum theory atomic structure and magnetism was laid in 1913 by Niels Bohr. From the point of view of magnetism the most important feature of the theory is

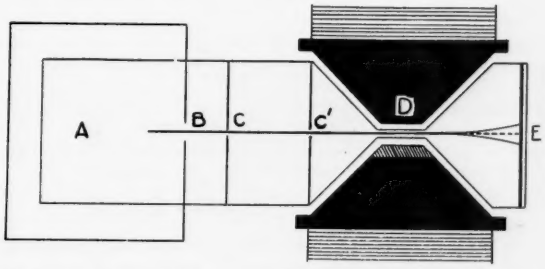


FIGURE 2.—DIAGRAM OF THE STERN AND GERLACH ATOMIC BEAM APPARATUS

that the orbital or spin moment of an electron can assume discrete values only—integral values of a fundamental quantum. Obviously, then, since the magnetic moment is simply related to these atomic moments, the theory implies that the magnetic moments must be multiples of a fundamental unit.

The immense amount of work that has been done in the last thirty or forty years has made it possible to trace back the phenomena observed to the atom itself. The results, however, do not afford any precise information as to the origin of magnetic behavior of the elements. Stern and Gerlach's experiments have shown how isolated atoms may be studied, but the method has been applied to only a few elements. Unfortunately, we cannot isolate the magnetic element from matter, as we can the electrical element, the electron.

Recent developments have shown that magnetism may arise in the atom from two sources other than

(*a*) orbital electronic moment.

In addition according to the theory propounded by Goudsmit and Uhlenbeck (*4*) an electron has

(*b*) an intrinsic spin moment which frequently predominates in certain types of atoms

The moment arising from

(*c*) nuclear spin is usually very small.

Bohr has pointed out that there is a very simple relation between the angular momentum of the rotating (or revolving) electron and the resultant magnetic moment. Elementary physics tells us that the angular momentum of a rotating body is equal to the product of the mass, the angular velocity, and the square of the radius of the path,

$$A = m\omega r^2.$$

Sidgwick (*3*) makes the following approximate derivation.

"On the classical theory of electromagnetism, if we regard the rotating electron (charge e) as equivalent to an electric current in a circular conductor, the magnetic moment is

$$\mu = \frac{1}{2}\frac{e \cdot \omega \cdot r^2}{c}$$

where c is the velocity of light.

"Hence the two quantities have the simple relation

$$\frac{\mu}{A} = \frac{1}{2}\frac{e}{m_e c}$$

Now in the Bohr theory the unit of angular momentum is $\frac{h}{2\pi}$ (h = Planck's constant). To this, therefore, there corresponds a unit of magnetic moment.

$$\mu = \frac{1}{2}\frac{e}{m_e c} \cdot \frac{h}{2\pi} = \frac{eh}{4m_e c\pi}."$$

The value of this unit depends only on well-known physical constants and one unit per mole has the value 5589 ergs/gauss. This value of the Bohr magneton is in direct accord with that found at a later date by the experiments of Stern and Gerlach.

CONVERSION OF C.G.S. UNITS TO MAGNETONS

When one measures the effect of a strong magnetic field on a substance, unless it is an individual atom (as in the Stern-Gerlach experiments), the measured value will be the resultant of the magnetic moments of many atoms. If these atoms are all identical and are perfectly free to orient themselves with respect to the magnetic field as separate units, the resultant effect is that of one atom multiplied by the number of atoms present. Unfortunately, such ideal substances are very rare. Stern and Gerlach have shown that ordinary nickel metal is composed of three different types of atoms of different magnetic moments. The determination of the magnetic susceptibility of nickel, *en masse*, then tells nothing of the magnetic moment of an individual nickel atom, but only the statistical average magnetic moment of all nickel atoms. Analogously the determination of the atomic weight of lead yields no knowledge of the weight of an individual lead atom but gives only the statistical average weight of all the isotopes of lead. The statistical average magnetic moment of a substance is its magnetic susceptibility, usually measured in standard c.g.s. units.

If one assumes

(*a*) that all atoms of a given element have the same magnetic moment, and

(*b*) that these atoms are free to act as separate units in a magnetic field,

the measured magnetic susceptibility of the element *en masse* may be converted into Bohr magnetons. The assumptions, however, are not usually justified. There are but few exceptions to the first assumption, but practically all elements *en masse* are exceptions to the second. In separating the elementary magnetic particles from the influence of one another by means of solution or vaporization the inferences of the second assumption can be realized in many cases. Indeed, in a few cases when paramagnetic ions crystallize, they do

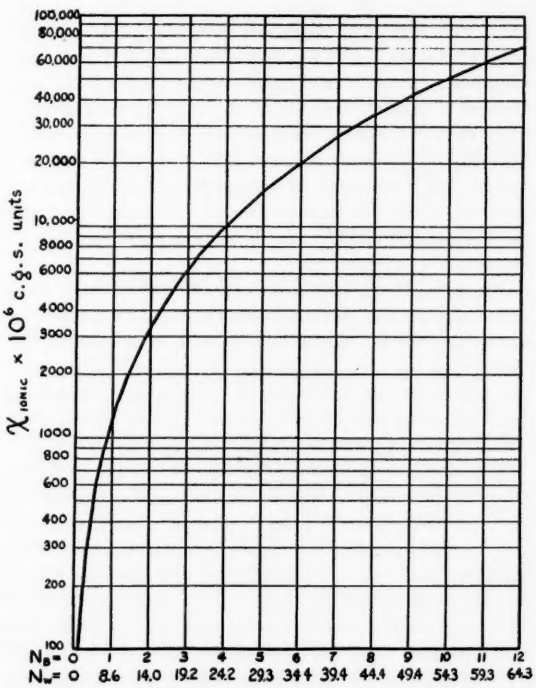


FIGURE 3.—CONVERSION GRAPH—MAGNETIC SUSCEPTIBILITIES INTO APPROXIMATE BOHR AND WEISS MAGNETON NUMBERS

so separated by diamagnetic ions, so that even in the solid state the paramagnetic ions are practically free of influence upon one another in a magnetic field.

Thus the magnetic susceptibilities of ions and molecules may be determined and these susceptibilities converted into statistical average Bohr magnetons, which shall be referred to hereafter as "effective magnetons." Whenever the molecules or ions measured each have the same magnetic moment and are perfectly free to act as individual units in a magnetic field, the effective magneton number must be a whole number if the Bohr magneton is truly a fundamental unit. Variations of the effective magneton numbers from integer values may be due to the presence of a very small percentage of ions

or molecules of different magnetic moment, or to mutual magnetic interference. Experimentally the influence of one paramagnetic ion upon another is minimized by dilution with a diamagnetic substance such as water.

The equation used by many workers to convert the magnetic susceptibility expressed in c.g.s. units into the convenient, but obsolete, Weiss magneton number is

$$(\mathrm{I}).....N_w = \sqrt{\frac{3RT\chi_{\text{ionic}}}{1124}}$$

where Nw is the Weiss magneton number, R is the molar gas constant (ergs per degree), χ_{ionic} (or χ_{molar}) is the magnetic susceptibility expressed in c.g.s. units per gram-ion (or per gram-mole).

If the Weiss magneton were literally $\frac{1124}{5589}$ or $\frac{1}{4.97}$ of a Bohr magneton, one could calculate the effective Bohr magneton number merely by dividing Nw by 4.97. This is not strictly true, however, and Sommerfeld has shown that for many atoms,

$$(\mathrm{II}).....Nw = 4.97\sqrt{N_B\,(N_B + 2)}$$

Where N_B is the statistical average Bohr magneton number—*i. e.*, the effective magneton number. If equations I and II are combined,

$$N_B^2 + 2N_B = \frac{3RT\chi_{\text{ionic}}}{(4.97 \cdot 1124)^2}$$

For ready conversion of χ_{ionic} into N_B a graph of this equation is shown in Figure 3. The magnetic susceptibility in c.g.s. units is plotted semilogarithmically against the effective Bohr and Weiss magneton numbers.

MAGNETIC ANOMALIES

In a solid crystal in which the paramagnetic ions are "close-packed" one might expect the tiny atom dipoles to interfere with one another. As a result the magnetism would be "quenched". Evidently this is actually the case. Weiss early found that Curie's law is not obeyed by most paramagnetic solids and ferromagnetic substances, but that a correction is necessary. The Curie-Weiss Law may be expressed as

$$\chi_{\text{molar}} = \frac{C_{\text{Molar}}}{(T - \theta)}$$

where the correction factor θ has the dimensions of temperature, and is known as the "molecular field or quenching constant." C is a characteristic constant.

Interpretation of the Curie-Weiss equation expresses the fact that as the absolute temperature approaches a certain value θ, characteristic of the substance, the magnetic susceptibility χ increases in value and approaches an infinite value. In other words the paramagnetic solid should become ferromagnetic at a definite temperature (Curie point) of $\theta°$ Abs.

However, although θ is positive for many substances at ordinary temperature, a true Curie point has not been found for any of the substances investigated at low temperatures. None become ferromagnetic. Cryomagnetic anomalies always seem to supervene.

Although a solid, the results for gadolinium sulfate octahydrate, $Gd_2(SO_4)_3 \cdot 8H_2O$, even at low temperatures, are in complete accord with the unmodified Curie law; that is, there evidently is no interference between the magnetic dipoles in this solid, and as a result they behave like the independent magnetic molecules of a paramagnetic gas. Ferric alum and gadolinium ethyl sulfate and several other similar salts also obey the unmodified Curie law to low temperatures. The substances in this case, it may be noted, are all magnetically "dilute," the inert part of the molecule—the anion and the water of crystallization—being large as compared with the active paramagnetic part.

In general, dilute solutions of paramagnetic salts obey Curie's law. However, in many cases the ionic susceptibility varies with the concentration of the solution. This is not totally unexpected since such equilibrium reactions, as that which occurs when anhydrous cupric sulfate dissolves in water, are well known. For example,

$$Cu^{++} + 4H_2O \rightleftharpoons Cu(H_2O)_4{}^{++}$$

in which the point of equilibrium is shifted upon dilution.

SIMPLE IONS

As previously pointed out, it is clear that the property of paramagnetism is due to incomplete electronic configurations and that magnetism of this character is not found in atoms, ions, or molecules possessing the complete electronic configurations of the rare gas type. However, the actual quantitative relationship between electronic configuration and magnetic properties is somewhat obscure at the present time.

The Bohr theory of atomic structure originally pointed out the spectral evidence for electronic energy levels or shells in the atoms, and later studies demonstrated the presence of sub-levels. Analysis of atomic spectra is thus very important in endeavoring to predict the magnetic properties of atoms, since it furnishes very precise information concerning the energy states (ground terms) of electrons within the atom.

Sidgwick (*3*) proposes that the magnetic properties of an atom do not depend so much on the completion of the major quantum levels as on the completion of the sub-levels forming so-called "Stoner grouplets" of electrons outside of the nuclei of the atoms. Whenever the Stoner grouplets are filled, a diamagnetic atom or ion results. Table 4 shows the detailed structure of radon, together with that of the transition element manganese, and will illustrate the meaning of the term "Stoner grouplet."

Fundamentally, the relationship between magnetism and the grouplets is as follows. The magnetic moment of an "empty" Stoner grouplet is obviously zero. One electron gives a magnetic moment of one Bohr magneton unit, two electrons, two Bohr magnetons, and so on until the grouplet is half complete. Then each addition of an electron decreases the moment by one unit, until finally the completed grouplet which possesses no magnetic moment is reached. (See Figure 4.)

In general, we have no information from spectroscopic data which can place the distribution of the electrons within the incompleted pairs of Stoner grouplets

as illustrated by the bracket in the case of manganese in Table 4. There is some evidence of electronic equilibrium in such sub-shells to which the characteristic color of the ion is often attributed.

The manganous ion is formed by the loss of the two $N - 1_1$ (or 4*s*) electrons from the manganese atom. If one applies the Stoner grouplet rule to the manganous ion it may be noted that there are three possible predictions for the Bohr magneton number of the ion.

(*a*) If the five electrons in the 3d grouplets are distributed *4, 1,* or *0, 5,* we should predict a magnetic moment of one Bohr magneton, for, as the structure of radon shows, the maximum numbers of electrons in these grouplets are 4 and 6, respectively.

(*b*) If the five electrons are distributed *1, 4* or *3, 2* we should predict a Bohr magneton number of three for the ion.

(*c*) If they are distributed *2, 3* we should expect a magneton number of five.

The observed magneton number of the manganous ion is *five,* indicating the last-mentioned distribution. In general, we reach the conclusion that two Stoner grouplets are often filled simultaneously. For the electronic configurations of the other atoms, the reader is referred to the complete tables in texts or handbooks.

The Stoner grouplet rule has been found applicable to most of the simple ions except those of the rare earth metals,* which show abnormally high susceptibilities. There are a few other exceptions, also, such as the diamagnetic form of the nickel atom and the diamagnetic platinous ion. In the cases of most of the apparent exceptions, the determination of the magnetic susceptibility has been carried out upon the substance in bulk, so that there is no assurance that the magnetic effects of the ions themselves are not quenched by their mutual interaction.

TABLE 4

Element	*Numbers of Electrons in Atomic Sub-Levels*																								
Bohr Term	$K1_1$	$L1_1$	$L2_1$	$L2_2$	$M1_1$	$M2_1$	$M2_2$	$M3_2$	$M3_3$	$N1_1$	$N2_1$	$N2_2$	$N3_2$	$N3_3$	$N4_3$	$N4_4$	$O1_1$	$O1_1$	$O2_2$	$O3_2$	$O3_3$	$P1_1$	$P2_1$	$P2_2$
Spectral Term	1s	2s	$2p^1$	$2p^2$	3s	$3p^1$	$3p^2$	$3d^1$	$3d^2$	4s	$4p^1$	$4p^2$	$4d^1$	$4d^2$	$4f^1$	$4f^2$	5s	$5p^1$	$5p^2$	$5d^1$	$5d^2$	6s	$6p^1$	$6p^2$
Rn	2	2	2	4	2	2	4	4	6	2	2	4	4	6	6	8	2	2	4	4	6	2	2	4
Mn	2	2	2	4	2	2	4	5		2														

FREE ATOMS

The observed magnetic susceptibilities of the elements are expected to agree with those which are predicted by the Stoner grouplet rule only if the atoms of the element are really free to orient themselves in the field. The interaction of the electrons in atoms when they combine to form molecules, as in the cases of chlorine and phosphorus, Cl_2 and P_4, respectively, results in the formation of a diamagnetic molecule, even when the *free* atom is paramagnetic.

Then, too, even if the molecule is monoatomic, the close-packing of the atoms in the solid crystal and even in the liquid state may result in the neutralization of all or nearly all the magnetic moments of the separate atoms. Thus we find that silver, *en masse,* is diamagnetic, while in the monoatomic vapor state (Stern and Gerlach experiments) it is paramagnetic, with a moment of one Bohr magneton. Atomic hydrogen has been shown by Phipps and Taylor (*1*) to have a magnetic moment of one Bohr magneton, but molecular hydrogen, H_2, is quite generally recognized as diamagnetic.

(*a*) Since none of the elements which are gaseous at room temperature are monoatomic (except the inert gases, which are diamagnetic), and (*b*) since we must have the element in the gaseous or monoatomic dissolved state in order to measure the magnetic moment or the magnetic susceptibility of the free atoms, the Stern and Gerlach type of apparatus is the only one which can, at present, give us the reliable magnetic moment of the free atoms. Because of the immense experimental difficulty in making the measurements by this method, we know only a few truly atomic susceptibilities.

In addition to silver and atomic hydrogen the atoms of sodium, potassium, copper, and gold have been found to have a moment of one Bohr magneton. The free atoms of zinc, cadmium, mercury, tin, and lead have been found to have zero magnetic moment. In each of these cases the Stoner grouplet rule predicts what has been experimentally found to be true. Nickel and thallium have been found to be anomalous. Nickel seems to be a mixture of three different types of atoms, one with zero magnetic moment, one with that of two Bohr magnetons, as the Stoner grouplet rule would predict, and a third with an uncertain but still greater magnetic moment. Thallium is still less certain, but appears to have a magnetic moment of about one-third of a Bohr magneton. This is probably caused by the incomplete separation of the atoms from each other, *i. e.,* by the presence of polyatomic molecules. Bismuth has not been determined in the atomic state, but in the molecular condition the gaseous state, as well as the solid, is diamagnetic.

Before one can be certain of the application of the Stoner grouplet rule as a general rule to free atoms, more determinations of the magnetic susceptibilities of free atoms must be completed.

* The magnetic phenomena of the rare-earth ions have been discussed adequately by D. W. PEARCE AND P. W. SELWOOD, J. CHEM. EDUC., **13,** 224 (1936).

COMPLEX IONS

It is obvious that the Stoner grouplet rule cannot be applied to such compounds as $[Co(NH_3)_6]Cl_3$ and $[Cr(NH_3)_5Cl]Cl_2$ until it is known how the electrons which form the coördinate links are distributed with respect to the central atom. This information is still a matter of conjecture.

Welo and Baudisch (*5*) have shown, however, that the difference between the "*effective atomic number*" of the central atom and the atomic number of the nearest inert gas in the periodic system is, in nearly every case, equal to the effective magneton number of the complex ion, or

$$[Z_{\text{eff.}} - Z_{\text{inert gas}}] = N_{\text{eff.}}$$

The "effective atomic number" (E.A.N.) is defined as the total number of electrons outside the nucleus directly associated with an ionic or combined atom. Thus the cobalt atom of atomic number 27 loses three electrons to form the cobaltic, Co^{+++}, ion (as in $CoCl_3$) of E.A.N. 24. If this ion is coördinated with six molecules of ammonia (donor molecules) it gains two electrons by each coördinate bond, giving the hexamminocobaltic ion $[Co(NH_3)_6]^{+++}$, ion of E.A.N. 36, the atomic number of the rare gas krypton, and $36 - 36 = 0$. Since the chloride, Cl^-, ions which are associated with this ion are diamagnetic it would be expected that the salt $[Co(NH_3)_6]Cl_3$ would have zero paramagnetic susceptibility. Rosenbohm (*2*) has shown that this compound is, in fact, diamagnetic.

Applying the same reasoning to the complex chromium compound, the chromium atom of atomic number 24 becomes the chromic ion, Cr^{+++}, of E.A.N. 21 on the loss of 3 electrons. Upon coördinating 6 units (5 ammonia molecules and 1 chloride ion), each of which furnishes 2 electrons, the ion $[Cr(NH_3)_5Cl]^{++}$ is formed, possessing an E.A.N. of $21 + 12 = 33$.

Since the nearest inert gas is again krypton, atomic number 36, we would expect by the Welo and Baudisch rule an effective magneton number of $36 - 33 = 3$ for the compound, $[Cr(NH_3)_5Cl]Cl_2$. Rosenbohm has determined the magnetic susceptibility of this compound and has found it to be 6390×10^{-6} c.g.s. units = 3 effective magnetons.

Rosenbohm (*2*) has reported the determination of the magnetic susceptibilities of some six hundred such complex compounds. Application of the Welo and Baudisch rule to these compounds yields, with a very few exceptions, the observed effective magneton number.

The complex nickel ions are anomalous, giving nonintegral effective magneton numbers, only roughly approximating what we would expect by the Welo and Baudisch rule. The complex salts of divalent platinum which have an E.A.N. of 84, are also apparently anomalous in that they are diamagnetic.

It has been pointed out that a single coördinated unit contributes two electrons to the coördinated bond. Certain molecules contain two coördinating groups. Such a compound is ethylenediamine, $NH_2—CH_2—CH_2—NH_2$ (usually abbreviated to *en*). Thus if both amino groups are coördinated to a single ion, a total of four electrons are donated to the linkages by the ethylenediamine molecule. The CO group contributes two electrons, but the NO group is peculiar in that it furnishes three electrons, one by transfer and two by sharing.

Various suggestions have been made regarding distributing the electrons of the coördinate bond in such a manner that the Stoner grouplet rule would account for the Welo and Baudisch rule and also for the few anomalies, but thus far no experimental evidence has been presented which favors one suggestion more than another.

In the cases of the molecules formed by purely covalent bonds between the atoms the Welo and Baudisch rule can also be quite satisfactorily applied. Thus in carbon dioxide, the E.A.N. of the carbon atom is $6 + 2 + 2 = 10$, each oxygen atom contributing two electrons to a double covalent bond. Similarly, the E.A.N. of the two oxygen atoms is each $8 + 2 = 10$, the carbon atom furnishing two electrons also to each of the double covalent bonds. The atomic number of the nearest inert gas is 10, that of neon, so we would expect the effective magneton number of CO_2 to be $10 - 10 = 0$. Carbon dioxide is diamagnetic. The fact that this rule applies quite generally to covalent compounds can easily be verified. In the great majority of cases, the compound will be found to have the effective atomic number equal to the atomic number of an inert gas, and will be diamagnetic. The O_2 molecule is an anomalous exception, having an effective magneton number of 2 for the molecule. Many workers have

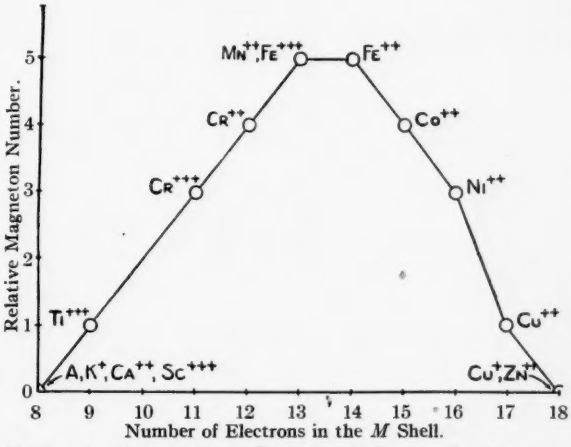


FIGURE 4.—PARAMAGNETIC SUSCEPTIBILITY AS A FUNCTION OF THE NUMBERS OF ELECTRONS

attempted to explain this anomaly, but thus far no simple explanation has been generally accepted.

APPLICATIONS

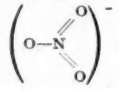
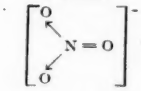
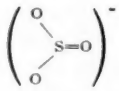
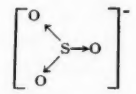
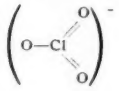
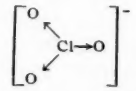
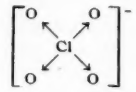
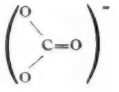
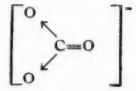
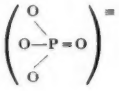
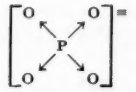
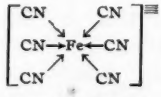
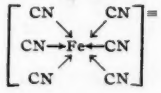
Magnetic susceptibility data are being employed very frequently in recent times to predict molecular structure and state of oxidation. This is especially useful with reference to complex ions, both positive and negative.

The hydrated ferrous ion and the sulfate ion may serve as examples. The magnetic susceptibility of the hydrated ferrous ion is approximately 4 Bohr magnetons. Since the atomic number of iron is 26, the E.A.N. of the ferrous ion is 24. The next inert gas being krypton (atomic number 36), the E.A.N. of the hydrated ferrous ion must be $36 - 4 = 32$. Therefore, the Fe^{++} ion must gain $32 - 24 = 8$ electrons by the coördinate bonds with the molecules of water of hydration. Since each water molecule furnishes two electrons to each bond, the ferrous ion must have associated with it four molecules of water—thus $[Fe(H_2O)_4]^{++}$.

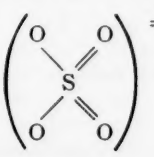
Similarly, since the sulfate ion is diamagnetic, each atom in it must have an E.A.N. equal to the atomic number of an inert gas. The E.A.N. of each oxygen atom (atomic number = 8) should be 10 (neon), and the E.A.N. of the sulfur atom (atomic number = 16) 18 (argon). If one represents a coördinate bond by an arrow pointing from the donor atom to the acceptor atom the sulfate ion may be represented as , two electrons having been gained by the sulfur atom, enabling it to be the donor of four pairs of electrons.

TABLE 5

THE STRUCTURE OF SOME COMMON IONS

	OLDER REPRESENTATION			NEWER REPRESENTATION			
Name of ion	*Formula*	*E.A.N.*	*Predicted N_{ett}.*	*Formula*	*E.A.N.*	*Predicted N_{ett}.*	*Actual N_{ett}.*
Nitrate		12	2		10	0	0
Sulfate		22	4		18	0	0
Sulfite		20	2		18	0	0
Chlorate		22	4		18	0	0
Perchlorate		24	4		18	0	0
Carbonate		10	0		10	0	0
Phosphate		20	2		18	0	0
Ferrocyanide	$[Fe(CN)_6]^{\equiv}$	—	—		36	0	
Ferricyanide	$[Fe(CN)_6]^{=}$	—	—		35	1	1

The E.A.N. of the sulfur atom is now 16 + 2 = 18, and that of each oxygen atom 8 + 2 = 10.

If the older representation  be interpreted to mean that two of the oxygen atoms are joined to the sulfur atom by double covalent bonds, and that the other two are joined to it by single covalent bonds, with the two electrons from the cation going to the latter two oxygen atoms, the calculated value of the E.A.N. of each oxygen atom is 10, but that of the sulfur atom is 16 + 2 + 2 + 1 + 1 = 22. This should give the sulfate ion on the basis of the Welo and Baudisch rules a magnetic moment of four Bohr magnetons, which is contrary to experimental evidence.

In Table 5 is shown a selection of the older and newer formulas of certain common anions on the basis of magnetic evidence. The E.A.N. of the atoms other than the central atom is in every case equal to the atomic number of an inert gas.

In the case of the ferro- and ferricyanide ions, no structure is indicated in the table for the cyanide radicals themselves. They are known to be diamagnetic, but no satisfactory structure has yet been generally accepted, though recent work has indicated that a transfer of an electron from the nitrogen to the carbon atom may take place, as is known to be true of the CO group.

It has already been pointed out that spectroscopic data give us no information concerning the exact distribution of *all* the electrons surrounding the nucleus of an atom or simple ion. As we have shown, in the example of the manganous ion, only one of the possible configurations allowed by spectroscopic evidence can account for the Bohr magneton number observed for this ion. Thus, in many cases the Stoner grouplet rule gives us additional knowledge of the detailed structure of atoms and simple ions. It should be noted, however, that there are outstanding exceptions to this rule of such a nature as to make it obvious that other factors, thus far unformulated, must be considered before the Stoner grouplet rule can be universally applied. The existence of a diamagnetic nickel atom cannot be explained by the simple application of the Stoner grouplet rule.

Magnetic studies thus offer a powerful tool in the investigation of atomic and molecular structure. Throughout the history of magnetism, hypothesis, experiment, and theory have all played their part. In general, unchecked mathematical speculation has been of little service to date, and there is still urgent need for accurate and systematic experimental knowledge.

* * * * * *

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SOYA PHOSPHATIDES

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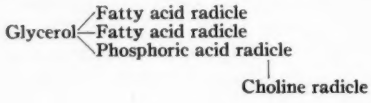
THE phosphatides are organic substances consisting generally of phosphoric acid, glycerol, higher fatty acids, and an organic base. They are present in every animal and plant cell. Egg yolk, the brain tissue, and the soy bean[1] are particularly rich in phosphatides.

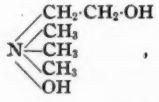
Soy beans contain in the average 40 per cent. protein, 20 per cent. fat, and a total of from 1.6 to 3.0 per cent. of the phosphatides, mainly lecithin and cephalin.[2]

LECITHIN

Lecithin is regarded as a body consisting of



Choline,



may be regarded as a substituted ammonium hydroxide in which one hydrogen atom is replaced by the oxyethyl group, and the other three by the methyl groups. The combination between phosphoric acid and choline is in the form of an ester, where the OH group of the oxyethyl group is substituted by the phosphoric acid radicle.

The principal distinguishing characteristics of soybean lecithin are the low proportion of saturated fatty acids (palmitic and stearic), the absence of unsaturated fatty acid containing a longer carbon chain than C_{18}, and the presence of linolenic acid.[3] Where four different fatty acids are available, there are theoretically possible seventy varieties of lecithin.

Lecithin is a yellow plastic wax-like mass which darkens rapidly on exposure to air. Lecithin is very labile, and undergoes changes as a result of oxidation, gradually becoming insoluble in alcohol and ether, and tending to become soluble in water.[4] The susceptibility of lecithin to oxidation is dependent on the presence of unsaturated fatty acid, and is increased by the presence of iron salts.

Lecithin forms addition compounds with certain salts of the heavy metals, such as cadmium chloride, platinum chloride, and mercuric chloride. The lecithin cadmium chloride obtained from soy beans differs from the salt prepared from animal materials in its behavior toward certain solvents. The cadmium salt from soybean lecithin is, for instance, insoluble in toluene, except when highly contaminated with cephalin.

Lecithin is highly hygroscopic. It swells in water and gives with excess water a turbid colloidal solution, from which it can be precipitated by acids or neutral salts, in particular by $CaCl_2$ and $MgCl_2$. Lecithin is soluble in ethyl ether, ethyl alcohol, petroleum ether, benzol, carbon tetrachloride, carbon disulfide, and chloroform, but is insoluble in methyl acetate and acetone. Though insoluble in pure acetone, lecithin may dissolve to some extent in acetone containing fat or fatty acids. In the presence of a small amount of NaCl, acetone readily precipitates lecithin from its emulsions with water. The α- and β-lecithins may be separated by the greater solubility of the β-forms in warm acetone.

Lecithin sols have a negative charge. The isoelectric point of pure lecithin is estimated as a pH of 6.4. In acid reaction lecithin can bind one equivalent of H ions, but is incapable of giving up one equivalent of H at alkaline reaction.

Aqueous and alcoholic solutions of lecithin are rapidly decomposed on heating by alkali, as well as acids into choline, glycerophosphoric acid,[5] and fatty acids. In the cold this reaction proceeds more slowly.

Lecithin possesses the property of forming on water monomolecular films,[6] which is due to the presence of two polar groups, the "hydrofobic" chains of fatty acids and the "hydrophilic" glycerol-phosphoric acid-choline radicle. On such films the chains are not located very densely, thus permitting the passage of other substances.

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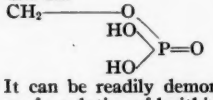
[1] In 1935 nearly 40,000,000 bushels of soy beans were harvested in the United States, and beginning with October, 1936, a future trade market in soy beans has been established on the Chicago Board of Trade.

[2] With but few exceptions it was found that the beans grown in the Eastern States contained less phosphatides than those from the West.

[3] For this reason the Iodine Number of commercial soya lecithin preparations lies between 90 and 100, while that of egg lecithin does not generally exceed 65. The high Iodine Number as well as the presence of phytosterin in soya lecithin serves for its differentiation from egg lecithin. The iodine value of lecithin decreases with the progress of oxidation.

[4] The original lecithin which is present in undamaged plant tissues is water-soluble but insoluble in organic solvents. During extraction by organic solvents the lecithin is believed to become denatured and acquires the property of being soluble in organic solvents.

[5] α-form (asymmetrical) of glycerophosphoric acid.



[6] It can be readily demonstrated by putting on water a few drops of a solution of lecithin in benzol.

In a general way lecithin seems to act on fats as a protective colloid, and it tends to prevent the separation of fractional constituents. When cooled, liquefied fats containing lecithin solidify to a homogeneous mass. Lecithin lowers the surface tension and the viscosity of fats, oils, creosote, etc., and also reduces the interfacial tension between these substances and water.

Lecithin owes many of its chief properties to its colloidal nature. The power of lecithin to make ether-insoluble substances, such as sugar, soluble in ether is due to the fact that it is a hydrophilic colloid, and so combines with water, and in this way takes up certain water-soluble substances. Lecithin does not generally act as a true solvent, but rather as an adsorbent. Many protein colloids which dissolve only in water are readily soluble in organic solvents, such as chloroform, when lecithin is present.

The greater part of the lecithin present in soy beans exists in some kind of combination with protein. While the free lecithin can be readily extracted by ether, the combined lecithin has to be liberated by the action of ethyl alcohol. Soya lecithin is also bound to a carbohydrate which can be only partly removed by the application of organic solvents. At least a part of this saccharide exists in firm chemical combination with the lecithin, for it is necessary to boil the lecithin for several hours with 5 per cent. H_2SO_4 in order to remove it. Usually soya lecithin contains up to 25 per cent. of a carbohydrate of a di- or polysaccharide type.

CEPHALIN

In the vegetable and animal kingdom cephalin is generally associated with lecithin.

Cephalin consists of

Glycerol — Fatty acid radicle
Glycerol — Fatty acid radicle
Glycerol — Phosphoric acid radicle — Colamine

Colamine, $\begin{matrix} CH_2 \cdot NH_2 \\ | \\ CH_2 \cdot OH \end{matrix}$,

amino-ethyl alcohol, is the characteristic base of cephalin.

The basic group of cephalin (Colamine) is weak while the acid group is quite strong, and it behaves toward NaOH as a univalent acid (at alkaline reaction cephalin gives up one equivalent of H ions).

Cephalin can be obtained in the form of a colorless solid body which is very hygroscopic and oxidizes rapidly in the presence of air to a brown-reddish mass. With water, cephalin forms suspensions and ultimately clear colloidal solutions.

Cephalin is soluble in ethyl ether,[7] in petroleum ether, chloroform, benzol, and hot ethyl acetate. Cephalin is insoluble in acetone, but, unlike lecithin, cephalin is insoluble in cold ethyl alcohol. However, the presence of lecithin partly protects the cephalin from being precipitated by alcohol.

The end-products of hydrolysis of cephalin by acids or alkalies are fatty acids, glycerophosphoric acid, and colamine, but it is somewhat harder to hydrolyze cephalin than lecithin.

Cephalin from soy beans shows no marked difference from the one isolated from animal sources. Commercial soya phosphatides (containing about 40 per cent. of oil) show usually an excess of cephalin over lecithin.

EXTRACTION OF SOYA PHOSPHATIDES

Soy bean oil, when pressed out by the expeller method, contains from 1.0 to 2.0 per cent. of phosphatides. It has been found that the precipitate separating from clarified expressed crude oil from soy beans grown in North Carolina and Virginia is composed chiefly of phosphatides.

The laboratory extraction of ground soy beans by organic solvents (in a Soxhlet apparatus) gave the following figures:

	Phosphatides (in Per Cent. of the Weight of Beans)
Carbon tetrachloride	0.27
Petroleum ether	0.41
Ethyl ether	0.49
Ethyl alcohol (96%)	1.56

The high results obtained by the ethyl alcohol extraction are due to the fact that alcohol not only extracts the free available phosphatides (dissolved in the oil) but splits off some of the lecithin from its combination with protein. Five parts of alcohol to one part of ground beans seems to be the optimum for Soxhlet extraction.

Laboratory extraction of phosphatides by benzine showed that:

a. While the oil requires from 1 to $1^1/_2$ hr. for extraction, the phosphatides require an additional three hours.

b. Twelve per cent. of moisture in the beans is the optimum for extraction efficiency during a given unit of time.

c. Where the beans have been stored in a dry warm place, the amount of phosphatides extracted per given unit of time decreases, while the amount of total extractible phosphatides remain the same.

d. Where the beans have been stored in a moist warm place the amount of phosphatides extracted per given unit of time is increased.

For commercial purposes 95 per cent. ethyl alcohol at a temperature of 75°C. is suitable for extraction of soya phosphatides. When the miscella, the liquor obtained in extracting the soy beans with ethyl alcohol, is cooled to room temperature, the oil and alcohol separate into two layers, the upper being an alcoholic solution of phosphatides and some admixtures, while the lower contains the oil. Treatment by $CaCl_2$ of the upper layer seems to give a satisfactory separation by coagulation of the phosphatides and carbohydrates from the alcoholic extract.

[7] Only if ether contains 1 per cent. moisture. The ethereal solution shows a greenish fluorescence.

Over a decade ago a plant was in operation at Imienpo, North Manchuria, China, where the oil and the phosphatides were extracted from the soy bean by the *Tcherdynzev* process, ethyl alcohol being used as the solvent. The ethyl alcohol extraction process is remarkable for its simplicity and the non-toxic nature of the solvent, and it would be particularly suitable for solvent extraction units of the rural type. It could also furnish an outlet for the industrial alcohol derived from such agricultural surpluses as corn, potatoes, and the like.

The *Bollman* process of extracting soya phosphatides depends mainly in the application of a solvent mixture of ethyl alcohol and benzol, which is able to dissolve lecithin and cephalin as well as oil, free fatty acids, resins, and bitter matter but leaves undissolved the carbohydrates soluble in alcohol. The most advantageous results are obtained by using a mixture of two parts alcohol and three parts benzol. The extract obtained from the process is warmed until the solvent mixture is vaporized. The oil, in which the lecithin is dissolved, protects the lecithin from decomposition. Into this mixture steam is passed in order to set free the lecithin. Care must be taken that the soy beans do not contain more than 10 per cent. moisture. When too great dilution takes place, the solvent mixture will separate into its constituent parts.

Where the extraction takes place with azeotropic mixtures of benzine and methyl alcohol (the *Mashino* method), the two solvents form one layer at the extraction temperature of 40–50°C., but after the extraction, the benzine layer, containing the bean oil, and the alcohol layer, containing the phosphatides, carbohydrates, coloring matter, and other impurities, separate at room temperature. By evaporating the upper benzine layer the purified oil is obtained, while the phosphatides and carbohydrates are recovered from the lower alcohol layer.

USES OF SOYA PHOSPHATIDES

Today they are numerous, such as in oleomargarine, frying fats, bakery products, chocolate, soap, cosmetics, as well as in the textile, leather, rubber, insecticides and wood-preserving (creosoting) industries.

AS OTHERS SEE US

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AS a rule students seem to resent having tests sprung on them unannounced. However, for the past nine years in the chemistry department at Greenville College one such test has been given each year.

This test occurs near the middle of the year. It is not a test of the students, but rather of the teacher. It is unique in that there is no chance for any student to fail, although the teacher may do so. The middle of the year is selected so that the students will know the teacher well enough to properly evaluate him and yet early enough in the year so the teacher may still have opportunity to redeem himself in the eyes of his pupils.

On a certain day small plain sheets of paper are handed to the members of the general chemistry class. A quiz is announced, which usually brings a degree of consternation, for such exercises are ordinarily held at regular intervals and are announced to the students beforehand. The students are asked to number their first question, which is as follows, "What do you consider my greatest weakness or fault as a teacher?" Panic reigns supreme, for they consider that this is a very risky business to be engaging students' attention. Of course, they have been thinking along this line but never expected to disclose it to the teacher. They are then asked to print or disguise their handwriting and leave the papers unsigned in order that they will run no risk of failing the course because of any prejudice aroused in the teacher's mind by the answers. They are told that this is their time to say some of the things which they have been thinking, under conditions where good may be accomplished.

Reassured as to the safety of the situation, they usually enter into the exercise whole-heartedly. The answers to the first question sometimes have to do with personal traits, while sometimes they take the form of criticism of the course itself. But in either case it is profitable to the teacher.

When the first question is fully answered, the second is given as follows, "What do you think is my best trait as a teacher?"

The answers have been tabulated and compared through the years. Casual answers which may only occur once in a given year are not considered seriously regardless of how complimentary they are. But if a given suggestion occurs repeatedly, it should really concern the teacher. It has been interesting through the years to note the gradual decrease of certain undesirable criticisms through the conscious efforts of the teacher.

This somewhat daring exercise gives a teacher an opportunity to view his personality and teaching habits through the eyes of his students. The writer believes that this very simple test has great possibilities from the standpoint of personality development and professional improvement.

EXPERIENCES TEACHING PROFICIENCY STUDENTS *in* CHEMISTRY*

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FRESHMEN who have studied chemistry in high school present a number of problems when they enroll for chemistry in college. Some of these freshmen rank much above the average in chemical knowledge and ability. Such students always present a challenge to the university. What should be done to meet the needs of these students?

It may be reasonably assumed that in many cases these students already possess a sufficient mastery of subject matter and laboratory technic to excuse them from existing courses in the regular curricula of the university. In other cases the assumption must be modified in this manner: these students are much more familiar with the subject of chemistry than the good high-school student, but this familiarity does not qualify them for any existing course. Rather, they are better fitted for a type of course which moves more rapidly over the work normally considered essential in the elementary study of chemistry and which is designed to strengthen the student's knowledge or skills wherever such strengthening is needed.

Experience gained at The Ohio State University indicates that the latter situation is the more common. Consequently for the past four years, the Department of Chemistry has offered a special course for these freshmen whom we call proficiency students. Since this procedure seems likely to interest other departments of chemistry, we submit this report of the undertaking.[1]

The Division of General Chemistry in this department has long offered two groups of courses in introductory chemistry: one group for those without previous high-school training (courses designated as Chemistry 401, 402, 403) and the other for those with previous training (Chemistry 411, 412, 413). Since 1926 the latter group, upon entering the university, has been given an examination, designated as the "placement test," to determine whether or not the applicant was properly qualified for admission to the more advanced first-year course. It soon became evident (1929) that this same examination might also be utilized to help select unusually well-trained students who might well be excused from the work of the first quarter (Chemistry 411) or be expected to complete the normal year's work (Chemistry 411, 412, 413) in two quarters. We followed each of these procedures for a limited time, but neither proved entirely satisfactory. By following the former, it appeared that the better student had somewhat of a handicap upon his entering the 412 course where his classmates had just completed the regular 411 work. When the student audited the regular lectures of the 411 course, moreover, this handicap was alleviated but not entirely surmounted. The latter plan of accelerated sections, while very gratifying to the Division, met with administrative difficulties in the reluctance of certain colleges within the university to grant three quarters of credit for two quarters of *work*.

During the academic year 1932–33 the entire situation changed materially. The university faculty adopted the general policy of granting entrance credit upon the successful passing of regular course examinations, to the extent of thirty quarter hours toward a baccalaureate degree. The adoption of this policy enabled us to select a group of superior freshmen students in the autumn of 1933, to give them credit for Chemistry 411, and to enroll them in a special section of Chemistry 412, peculiarly adapted to meet their needs. Such a procedure has now been followed for four successive years. No administrative difficulties have been encountered, aside from some lack of uniformity among the various colleges as to what constituted a satisfactory grade in order that entrance credit be granted. Even here complete uniformity has been obtained this year with the adoption of a general policy that an applicant, to receive entrance credit in an authorized course offering, must obtain a grade of "B" or better in the examination covering that course.

The announcement in the university bulletins of a section of a course not normally given in that quarter has always resulted in numerous requests from regular students for permission to take the course with the proficiency group. Even a frank statement of the character of the course and its objectives has not always served to discourage these students because most of them have some urgent reason why this particular chemistry course must be taken at that particular time. Yet withal, this latter group has not interfered greatly with the conduct of the course but rather has afforded,

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* Based upon a paper presented before the Division of Chemical Education at the ninety-third meeting of the A. C. S., Chapel Hill, N. C., April 13, 1937.

[1] An earlier report on the proficiency course in elementary chemistry was given by the late PROFESSOR J. E. DAY, J. CHEM. EDUC., **12**, 166–8 (1935).

for purposes of evaluation, a control group within the course itself. There can be little doubt that the regular students have found the course rather difficult at times. However, the general performance of these students is good and one may venture the conclusion that many of them have forced themselves to better performance because of their desire to take advantage of an opportunity extended them and because of the competition and general attitude of seriousness on the part of their classmates.

SELECTING THE PROFICIENCY STUDENT

The first problem in any such course as that outlined above is to determine who of the entering class are superior students. Our own problem was somewhat more complicated in that we were not only picking the better students but also granting credit for an existing course. It is conceivable that we *might well supplement* a student's background through a *special course;* whereas his previous training might have left him somewhat untrained in certain directions were he to go directly into a regular section of the second quarter's work. Consequently, we utilized the "placement test" as a preliminary rating device. The students ranking highest (down to the 89th percentile) in this test as well as those others who expressly requested the privilege were then given a proficiency examination.

The proficiency examination consisted of two parts: (*a*) a written section, and (*b*) a section consisting of actual laboratory manipulations. The written portion of this examination (two to three hours) was of a comprehensive character and designed to be the equivalent of a somewhat difficult final examination over our regular 411 course. Such proficiency examinations cover, therefore, the following topics: matter and energy; oxygen, hydrogen, and water; the gas laws and the kinetic-molecular theory; the atomic theory; calculations; valence; the states of matter; carbon and its oxides; nitrogen and its compounds; the atmosphere and the rare gases; solutions; chlorine; sodium; salts, acids, and bases; ionization and its applications; and equilibrium.

The reasons for giving a laboratory examination are fairly obvious. Students come by their knowledge of chemistry in different ways: *i. e.*, high-school experience and training, reading, home laboratory, etc. The high schools of the state differ greatly in the emphasis placed upon laboratory work. Some have well-equipped laboratories and give their students very good training. Others have very meager equipment, hardly enough to give the student any training. Still others, because of curtailed budgets, offer no laboratory work whatever and few demonstrations by the instructor. In the home laboratory the young enthusiast seldom disciplines himself to real investigational practice but is attracted largely by the spectacular or entertainment aspects of chemical reactions. Since chemistry is an experimental science, we take the position that no full understanding of this science can be obtained without some real laboratory experience. Consequently, we desire to know if the proficiency student is familiar with the common types of simple laboratory apparatus, is capable of executing the simple operations involving this apparatus, and, finally, is capable of carrying out an experiment to obtain some definite result.

Our procedure has been to take some fairly simple experiment with which we have had sufficient experience to know that the directions are not confusing and will give a definite result if followed with reasonable care. The particular experiment must also involve a number of simple manipulations such as weighing on a chemical balance, burner operation, glass working, alignment of parts, etc. The particular exercises chosen during the past four years have been: (1) determination of the valence of magnesium (hydrogen evolved);[2] (2) an exercise involving distillation, neutralization, and evaporation; (3) determination of the molecular weight of a volatile liquid (vapor density);[3] and (4) determination of the per cent. of oxygen in potassium chlorate and of the molecular weight of oxygen.[4] When the students report to the laboratory, the instructor in charge explains carefully the character and purpose of the examination. Each student is then given a mimeographed sheet of instructions and a set of equipment containing everything necessary for performing the experiment. At no time during the examination is any aid offered the student except in those occasional cases where he has gone off on such a tangent that he is likely to endanger himself, or his neighbor, or where he has become so hopelessly confused

TABLE 1

SCORE CARD FOR LABORATORY PROFICIENCY EXAMINATION, 1936

With averages of (1) those granted advanced credit, and (2) those not granted advanced credit

Maximum grade on each part is 4.00.

		1	2
1.	Handling of Bunsen burner	3.50	3.36
2.	Glass work: bending, fire polishing	3.06	2.39
3.	Putting glass tubing through stopper	2.72	2.58
4.	General appearance of final set-up	3.13	2.92
5.	Handling of balance	2.97	2.40
6.	Determination of zero point	1.91	1.35
7.	Speed of weighing	2.78	2.79
8.	Manner of heating test-tube	3.44	3.15
9.	Efficiency of gas collection	3.66	3.21
10.	Measuring volume of gas	2.88	2.46
11.	Cooling the test-tube	3.22	2.64
12.	Accuracy in weighing	3.31	2.98
13.	Transfer of residue to beaker	3.28	2.99
14.	Preparation of filter	3.25	2.76
15.	Filtration	3.22	2.70
16.	Recovery of KCl	3.13	2.30
17.	Orderliness of data table	3.41	3.21
18.	General organization of work	3.13	2.82
19.	Neatness of desk	3.28	3.26
20.	Cleaning up operation	3.44	3.37
21.	Total time used	3.41	3.08
22.	Equation	3.47	3.51
23.	Answers to questions	3.16	2.88
24.	Calculation of % of oxygen	3.38	2.72
25.	Calculation of molecular weight	2.56	1.38

[2] MCPHERSON, W., W. E. HENDERSON, AND W. L. EVANS, "A laboratory manual arranged to accompany a course in general chemistry," 4th ed., Ginn and Co., New York City, **1934**, 45–6.

[3] BAILAR, J. C., JR., "Laboratory assignments for Chemistry 2" (University of Illinois), Edwards Bros., Ann Arbor, Mich., Assignment 6, Part II.

[4] Ref. 2, 27–8.

that he is missing the entire point of the operation. The graduate instructors assisting in this examination observe the student carefully, and record on a rather elaborate score card (see Table 1) the performance of each student under their care during each of the separate operations of the experiment. From the partial grades on each of these operations a final grade is computed.

The laboratory grade is considered along with that on the written examination in the final choice of those eligible for "Em" credit examination and admission to the proficiency course. In general a relative weighting of two has been assigned to the written work and of one to the laboratory work. Not only the weighted single score but also the items contributing to it are considered as separate evidence upon which to form judgments about the students. During the present year, the final choice was made during a general conference of all instructors involved in the examination. In this way ample opportunity was given for full discussion of all doubtful cases.

Data relative to the group of proficiency students are given in Table 2.

DEFICIENCIES IN THE PREVIOUS TRAINING OF PROFICIENCY STUDENTS

In the previous discussion, it is evident that we recognize a distinct overlapping in our training of the student and that which he has received before he enters our courses. Nevertheless, we are convinced that our courses differ markedly in the point of view, emphasis, subject matter covered, etc., over that of the ordinary high-school presentation. It is only very infrequently that a student comes to us in possession of all of the things which we consider essential.

TABLE 2

DATA RELATIVE TO PROFICIENCY STUDENTS

Year	*1*	*2*	*3*	*4*	*5*	*6*
1933–34	598	77	29	1	2	
1934–35	956	102	34	5	4	1
1935–36	1085	126	42	1		1
1936–37	1287	124	33	1		1

Column 1. Number of students who took the placement test (Autumn Quarter)
Column 2. Number of students who took the proficiency examination (Autumn Quarter)
Column 3. Number of students who passed the proficiency examination and enrolled in the proficiency course.
Column 4. Number of students who passed the proficiency examination but declined credit for Chemistry 411.
Column 5. Number of students who passed the proficiency examination (Autumn Quarter) but did not enrol in the proficiency course.
Column 6. Number of students passing special proficiency examinations (given upon request at some time other than the Autumn Quarter).

Since the idea behind our proficiency course is to supply that which has been missed or omitted previously, we must give some consideration to those items which in general seem to be lacking in our proficiency students. We have observed that these students:

1. *Do not realize the significance of the theories of chemistry.*

In other words, these students fail to understand and visualize phenomena in terms of the entities or characteristics postulated to explain and correlate them. The student is thoroughly familiar with the terms atom and molecule and the postulates of the kinetic theory, but he does not use these concepts to visualize phenomena about him or apply them to new phenomena which he encounters.

2. *Do not understand the real significance of the scientific method.*

For example, a student is familiar with the concept of an ion, but he has little understanding of how the behavior of electrolytes leads to the concept of an ion. In other words, he confuses an experimentally determined fact with the theoretical interpretation given to account for the existence of that fact and to correlate that particular fact with other facts similarly determined.

3. *Do not possess familiarity with quantitative experimentation.*

During previous training the attention of the students has been directed toward answering the question "what?" and "in which direction?" rather than "how much?" Consequently, we direct our attention to supplying this need. We can do this rather easily because such students usually possess a considerable factual knowledge which only requires a different interpretation.

CHARACTER OF THE PROFICIENCY COURSE

Briefly stated the aims of the course for proficiency students are these: (1) to supply the deficiencies in the student's previous training: *e. g.*, to supply that which he has missed by not taking Chemistry 411, and (2) to go more deeply into the material normally covered in the courses Chemistry 412 and 413. There remains then to outline the content of these two courses.

Chemistry 412 (for proficiency students). The content of this course may be seen best by giving the titles of the lectures.

1. Matter and energy as fundamental concepts. The scientific method. The kinetic-molecular theory. The atomic theory.
2. Determination of molecular and atomic weights. Interpretation of the symbolism of chemistry.
3. The states of matter. Solutions.
4. Ionization and its applications.
5. Equilibrium.

These lectures are designed to meet the first aim stated before. In each case the difference between experimental fact and theoretical interpretation is stressed.

6. The periodic law. Radiation. Atomic numbers. Evidence for the existence of electrons. Radioactivity.
7. Isotopes. Atomic structure. Types of chemical bonds.
8. The halogens.
9. Oxidation-reduction reactions.

10. The colloidal state of matter.
11. The nitrogen family.
12. The sulfur family.
13–14. Organic chemistry.

Since the students are already familiar with much of the subject matter of these topics, it is possible to treat them in a fairly mature fashion and to give practice in the use of general concepts and theories. Each topic is supplemented by carefully chosen home-work exercises.

The laboratory portion of this course is divided into two parts. The first part (approximately two-thirds of the quarter's work) follows the lectures very closely and stresses the quantitative aspects of chemistry. During the present year the exercises chosen were: Graham's law of diffusion, molecular weights (vapor density and cryoscopy), titration (volume and concentration relationships, equivalent weight of an unknown acid, and conductimetric titration), degree of ionization (cryoscopy), rate of reactions, equilibrium and hydrolysis, colloidal system, thermal analysis, periodic relationships (atomic volume and specific heat as functions of atomic number), and atomic structure (properties of cathode rays, spinthariscope, and spectroscope). The latter part of the laboratory work is devoted to qualitative analysis (an exercise on group separations and Cation Groups I and II).

Chemistry 413 (for proficiency students). Following a general lecture on metals, their occurrence and metallurgy, this course is devoted to qualitative analysis. Not only the chemical reactions but also the points of theory involved in the separations and identifications are considered. The theoretical treatment includes the applications of equilibrium (ionization constant, solubility product, common-ion effect, instability constant, pH, ampholytes, etc.), oxidation-reduction reactions, and coördination number. These topics are treated in more detail than is done in the regular course. At the same time, however, the above considerations are not stressed to the extent of overshadowing the determination of unknown samples in the laboratory.

PERFORMANCE OF PROFICIENCY STUDENTS

From the nature of the proficiency course outlined above, therefore, one can readily see that a good deal more is expected of the proficiency students than is expected of students in the regular courses. The question then arises: *What is the basis on which grades in the proficiency course shall be given?*

One may decide to give grades on the same distribution as normally. To do so, however, would place some of the proficiency students at a disadvantage when scholarship ratings are computed and when the students present themselves for entrance into professional schools. One may decide, on the other hand, that, since these students are already carefully chosen, they are all worthy of an "A" grade. To do this, one presupposes (1) that his system of choosing is perfect and (2) that early proficiency guarantees continued proficiency. However, we admit that our scheme of testing is not yet perfect (and probably never will be) and we doubt the validity of the second supposition.

There remains, then, only one alternative: namely, for the instructor to rate his students as best he can, in accordance with the usual standards of performance in the regular course. Numerical grades in various parts of the work, character of classroom discussions, observations of laboratory work, etc., are all factors which are taken into consideration. Following this procedure the grades given to proficiency students are those tabulated in Table 3.

TABLE 3

DISTRIBUTION OF GRADES OF PROFICIENCY STUDENTS

A. Enrolled in Proficiency Course

Grade	*1933–34*		*1934–35*		*1935–36*		*1936–37*		*Total*	
	412	*413*	*412*	*413*	*412*	*413*	*412*	*413*	*412*	*413*
A	14	16	16	13	9	13	13	15	52	57
B	11	9	10	15	14	7	11	10	46	41
C	4	2	8	4	17	16	9	6	38	28
D	—	—	—	—	1	2	—	1	1	3
E	—	—	—	—	1	1	—	—	1	1
	29	27	34	32	42	39	33	32	138	130

B. Enrolled in Regular Course

A	1	1	—	—	1	1	1	—	3	2
B	1	1	4	2	—	—	—	—	5	3
C	—	—	1	1	—	—	—	—	1	1
D	—	—	—	—	—	—	—	—	—	—
E	—	—	—	—	—	—	—	—	—	—
	2	2	5	3	1	1	1	—	9	6

In connection with the grades given, there are a few points that deserve some consideration. Thus it may seem that the number of students chosen is surprisingly small in proportion to the number entering with previous chemical training (Table 2). We approached the matter as an experiment and attempted to move cautiously. In view of the increasing enrolment in elementary chemistry and of the apparent success of the proficiency courses, we admitted a somewhat larger number of students in the year 1935–36. To do this we had to stretch our conscience a good deal in several doubtful cases. It was soon evident that a few students had been given entrance credit who were barely able to handle the proficiency work. This situation is reflected in the grades earned. Dropping back to a somewhat smaller figure during the present year, the performance of the students has become very satisfactory.

Inasmuch as our proficiency courses have always had a number of regular students enrolled in them, it is of some interest to compare the performance of the two groups. We wished to avoid working any hardship on the regular students just because they happened to take their chemistry with a proficiency group. Hence we always treated each group separately in the assignment of final grades. Over a period of four years, only two regular students have proved to be as good as those in the upper third of the proficiency group. On the other side of the picture, about half of the regular students are poorer than the lowest proficiency student (not true in the case of three proficiency students in 1935–36). Examination averages consistently show the level of

performance of the proficiency group to be 10–20% higher (usually 15–18%) than that of the regular students.

PROFESSIONAL INTERESTS OF PROFICIENCY STUDENTS

The distribution of proficiency students by colleges (Table 4) shows that slightly more than half of the group (51.7% or 76 out of 147) is registered in the College of Engineering. The College of Arts and Sciences ranks next with 34.0%, while the College of Agriculture contributes 6.1%, Commerce and Administration 4.1%, and all others 4.1%. A more detailed analysis of the majors of proficiency students shows that 51 or 34.7% are following the chemistry and chemical engineering curricula. The closely allied fields of ceramics and metallurgy contribute another 17 or 11.6% while only 10 or 6.8% are majors in fields that cannot logically be included under the terms "science" and "science technology."

ORIGIN AND EARLY CULTIVATION OF INTERESTS OF PROFICIENCY STUDENTS

What is the background of the students selected as being proficient in chemistry? What factors have contributed to their interest in chemistry? Answers to these questions were sought individually during friendly conversations in the laboratory. An analysis of the present group is typical. Of thirty-three students, seventeen definitely trace their interest in chemistry to their high-school courses. The other sixteen, however, had a definite interest in chemistry prior to their taking the high-school course. Six of these had purchased one of the chemistry sets to be found on the market and had set up home laboratories. This early interest was greatly fostered by high-school experience, particularly where they had free access to the laboratory or had become assistants. Three students selected their major field because of professional interests in the home (druggest, physician) or the industries of the community (steel mills). An early interest in electricity led two students to decide upon a career in chemistry. In three or four instances, a major interest in some other science led the student into chemistry. In every case of this type the person recognizes the importance of chemistry to other sciences. Two of the students are majoring in physics and have been granted entrance credit in mathematics to the extent of ten and fifteen hours respectively. One other student has five hours of entrance credit in German. In one instance the high-school course was followed by the purchase of a chemistry set and the establishment of a home laboratory. In at least a dozen cases preparation for the state scholarship examinations was a potent factor. In one interesting case, literature and chemistry were vying for the boy's professional interest during high school. The proficiency course caused him to decide in favor of literature.

In all cases it is evident that one is dealing with unusually capable students. This is reflected by the definiteness of their professional interests and by the diligence with which they are preparing for their careers.

TABLE 4

DISTRIBUTION OF PROFICIENCY STUDENTS BY MAJORS

A. Enrolled in Proficiency Course

Major	*1933–34*	*1934–35*	*1935–36*	*1936–37*	*Total*
AGRICULTURE					
Agricultural Chemistry	—	1	—	—	1
Agricultural Engineering	—	—	1	—	1
Animal Husbandry	—	1	—	—	1
Entomology	—	—	2	—	2
Home Economics	2	—	—	—	2
Total	2	2	3	—	7
ARTS AND SCIENCES					
Anatomy	1	—	—	—	1
Bacteriology	1	—	—	—	1
Biology	4	1	—	—	5
Chemistry	5	5	7	5	22
Dentistry	—	—	1	—	1
Economics	—	1	1	—	2
English	—	—	—	1	1
Geology	—	—	—	1	1
Mathematics	1	—	—	—	1
Medicine	—	4	3	2	9
Physics	—	—	—	2	2
Psychology	—	1	—	—	1
Zoology	1	—	—	—	1
Total	13	12	12	11	48
COMMERCE AND ADMINISTRATION					
Accounting	—	—	1	—	1
Foreign Commerce	2	—	—	1	3
General Business	—	1	1	—	2
Total	2	1	2	1	6
EDUCATION					
Chemistry	—	—	—	1	1
None	—	—	1	1	2
Total	—	—	1	2	3
ENGINEERING					
Architecture	—	—	1	—	1
Ceramics	1	—	4	1	6
Chemical	4	6	6	8	24
Civil	2	—	2	—	4
Electrical	1	3	3	1	8
Eng. Physics	—	—	4	1	5
Industrial	1	1	1	—	3
Mechanical	2	3	—	3	8
Metallurgical	—	5	2	4	11
Mining	—	1	—	—	1
Total	11	19	23	18	71
PHARMACY	—	—	1	—	1
VETERINARY MEDICINE	1	—	—	1	2

B. Enrolled in Regular Course

AGRICULTURE					
Dairy Technology	—	2	—	—	2
ARTS AND SCIENCES					
Bacteriology	—	1	—	—	1
Chemistry	—	—	1	—	1
	—	1	1	—	2
ENGINEERING					
Chemical	1	—	—	1	2
Civil	1	—	—	—	1
Electrical	—	2	—	—	2
Total	2	2	—	1	5

One cannot refrain from observing at this point that some of these promising individuals have not been properly advised in the high school as to the best courses to fit them for scientific work. Several come to college poorly grounded in mathematics, and many are startled to learn that Spanish is not as useful a language as German or French for the scientist.

Granting that an early interest in chemistry and the proper cultivation of such an interest during the high-school course are potent factors in acquiring proficiency in chemistry, one still looks for other contributing factors. To gain information on this point, each of the present group of proficiency students was questioned to determine what outside work he was doing and what extra-curricular activities occupied his attention. The replies to these questions were very interesting. Only nine out of thirty-two were working while attending the University. The number of hours of work per week ranged from twenty-five to five with an average of 12.7 hours for the nine students concerned. Only five members of the group belong to a social fraternity. Of the fifteen who listed some extra-curricular activity, five were members of musical organizations, three were active in athletics, two others were interested in the rifle club, one was a junior member of his professional society, while the other five were interested in very minor activities. Unfortunately, no data on avocations and hobbies were obtained. One might gain the impression that this group of students is made up essentially of "bookworms" and "grinds." Any contact with them, however, contradicts such an idea. The principal difference between them and the average group of students seems to lie in these directions: (1) they have a singleness and definiteness of purpose and (2) they experience real pleasure in pursuing their own professional interests.

GENERAL PERFORMANCE OF PROFICIENCY STUDENTS

It is conceivable that an intense interest in chemistry may not always parallel a high general scholarship average. The data in Table 5 throw light on this situation. Today it is customary to insist not only on a certain quantity of course work, but also on a certain quality of performance. At The Ohio State University this is done by computing a "Point-Hour Ratio" which is the quotient of the number of quality points divided by the number of course hours. For each hour of credit with an A grade, four points are given; for a B, three; for a C, two; for a D, one; and for an E (failure) none, although the number of hours of failure is counted in the divisor. A point-hour ratio of 4 would then mean a straight A record. At the present time no member of any chemistry proficiency course has such an average (as a matter of fact, a negligibly small number of students maintain a straight A average). However, 85 out of 147 (57.8%) have an average of B or better, and of the remainder 54 (or 36.7% of the entire group) have an average between B and C. The eight students having averages below C indicate one direction in which we should strive to perfect our technic for determining the proficiency student. A review of the performance of the few (eight in four years) who declined proficiency credit indicates that in these cases we were not entirely wrong in our choice.

ASPECTS OF THE PROBLEM DEMANDING FURTHER STUDY

A fundamental question, which we feel has not as yet been entirely solved, is the selection of those students who are already proficient in chemistry. It has been mentioned before that a few students have been admitted to the proficiency course who did not measure up to the standard of the rest of the group. Fortunately,

TABLE 5

POINT-HOUR RATIO OF PROFICIENCY STUDENTS

A. Enrolled in Proficiency Course

Point-Hour Ratio	*1933–34*	*1934–35*	*1935–36*	*1936–37*	*Total*
Above 3.5	6	4	12	12	34
3.0–3.49	•10	13	11	11	45
2.5–2.99	9	9	9	6	33
2.0–2.49	4	5	7	2	18
1.5–1.99	—	3	1	1	5
1.0–1.49	—	—	1	1	22
Failure (0)	—	—	1	—	1
	29	34	42	33	158

B. Enrolled in Regular Course

Above 3.5	1	—	1	—	2
3.0–3.49	1	2	—	1	4
2.5–2.99	—	2	—	—	2
2.0–2.49	—	1	—	—	1
	2	5	1	1	9

the number of these students is not large. On the other side of the picture, our instructors each year find a few students (perhaps a dozen) in the regular course who stand well above the normal good student. The question naturally arises, "Why aren't these students in the proficiency course?" Upon examining such cases one finds the following situations:

1. The student refused proficiency credit. The motivation behind such refusal is usually the fear of additional work, of lower grades than would be obtained in the regular course, and of missing some of the essentials of the elementary course.

2. The student failed to take the proficiency examination. The reasons given here are similar to those above. On several occasions students who have completed the laboratory part of the examination fail to present themselves for the written part.

3. The student failed to take the "placement test." This test is given prior to the beginning of classes during freshman orientation week and is required of all students entering with chemistry credit and planning to take further chemistry in the University. Late registration, incorrect information, or change of course after entering the University are the factors involved here.

4. The student entered with a relatively poor background in chemistry but developed rapidly in our courses.

5. The student's performance in our examinations was clearly not up to the standard which he might have been expected to attain.

If a student is thoroughly convinced that he doesn't want proficiency credit, we do not force him to accept

it. However, we always like to give him a clear picture of what is involved so that his choice is not based upon misinformation. Great care is taken that our examinations (both placement and proficiency) are clearly announced in the official publications of the University, on our bulletin boards and orally, in our early contacts with the students. It is essential also that the various counseling groups within the University have a clear picture of what we are attempting to do so that they do not give wrong impressions. The proficient student missed by our examinations is the real problem. Further, it is not a particularly easy one since we are called upon to predict success in college chemistry before we have had any opportunity to observe the students in a college environment. We must find additional questions, the successful answering of which depends more upon the *reasoning* ability of the student and less upon his *memory*. Then, too, it seems that some weight should be given to the student's choice of profession and to his non-classroom contacts with chemistry, such as laboratory assistant, home laboratory, and reading in science.

CONCLUSION

After four years experience with the proficiency course, we have reached the following conclusions. (1) We are at least sufficiently well satisfied with the results to wish to continue the experiment. (2) Without sacrificing any academic standards, we are recognizing in a material way high-school proficiency. (3) We feel that we have an effective way of bridging whatever gap there may be between the high-school and the college course. (4) With a selected group of students, we have been able to go more deeply into the science of chemistry than we can with the regular students.

ACKNOWLEDGMENTS

The authors wish to acknowledge their great indebtedness to their late colleague, Professor J. E. Day, who originally organized the present course for proficiency students and who conducted the work during the first two years of its existence. Throughout our experiments with proficiency students we have enjoyed the coöperation of all of our colleagues. We wish to take this opportunity to express our appreciation to Dr. G. B. Bachman and Dr. A. B. Garrett for preparing and conducting some of the proficiency examinations and to the many graduate instructors who have served so loyally in various phases of the work. We owe a great deal to Dr. R. W. Tyler and Dr. F. P. Frutchey of the Bureau of Educational Research for their constant counsel and help in preparing examinations and in evaluating the various objectives which we set out to accomplish. Finally, we wish to thank Dr. W. H. Cowley for his helpful criticisms of the manuscript.

The ROW *of* INCREASING ATOMIC WEIGHTS *and the* PERIODIC LAW

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AS IS well known, Mendeléeff placed all elements in a row of their increasing atomic weights and discovered the periodicity of their chemical and physical properties. In order to fulfill the requirements of the periodic law he had to reverse their sequence in three well-known cases, namely:

$$_{18}\text{A}\ (39.9) \longleftarrow {}_{19}\text{K}\ (39.1)$$
$$_{27}\text{Co}\ (58.9) \longleftarrow {}_{28}\text{Ni}\ (58.7)$$
$$_{52}\text{Te}\ (127.5) \longleftarrow {}_{53}\text{I}\ (126.9),$$

to which recently the fourth[1]

$$_{90}\text{Th}\ (232.1) \longleftarrow \text{Pa}\ (231)$$

should be added.

In the past this fact has always been brought out (practically in all textbooks), and properly so, as the main inconsistency in the periodic system. Although since Moseley's proof in 1913, that the exact sequence of the elements in the periodic system is given by their nuclear charges, a reference to atomic weights is not compelling, it is important to point out that: *the row of increasing atomic weights is identical with the sequence of increasing nuclear charges*, if one frees oneself from the outgrown assumption that the so-called *practical values* of atomic weights must be used.

The practical values have actually ceased to be representative constants of the elements ever since F. Soddy's introduction of the concept of isotopes and

[1] A. V. GROSSE, *J. Am. Chem. Soc.*, **56**, 2501 (1934); *Proc. Royal Soc.*, London, **A150**, 363 (1935).

F. W. Aston's discovery of isotopy among the common elements in 1913. This because from the standpoint of the periodic law *any* isotope of an element is as good

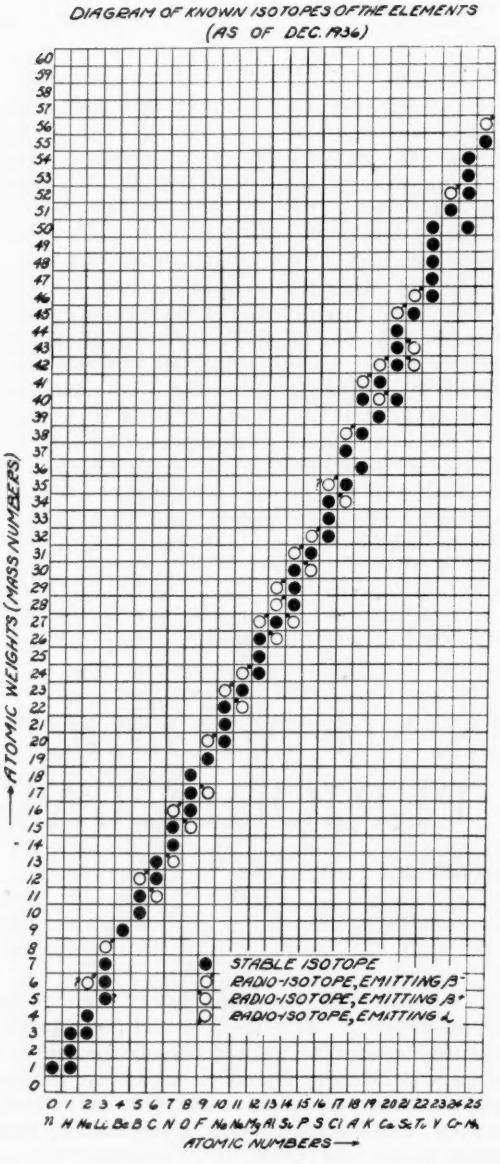

FIGURE 1

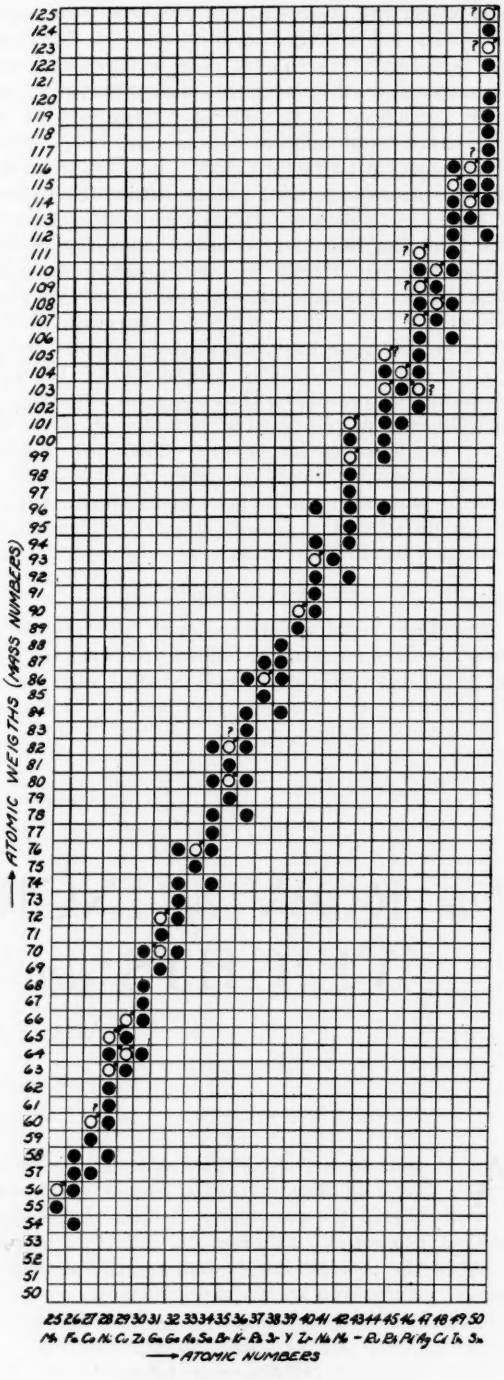

FIGURE 2

a representative of it as another, disregarding whether it is abundant or rare, stable or radioactive, since all of its properties *described by the periodic law* are identical.

For this reason a mathematical function giving equal weights to *all* isotopes of an element, the simplest being the *arithmetic mean* of atomic weights of all atomic species of an element, is a much more

logical constant of an element *for the purposes of the periodic system* than the practical atomic weight of the analytical chemist.

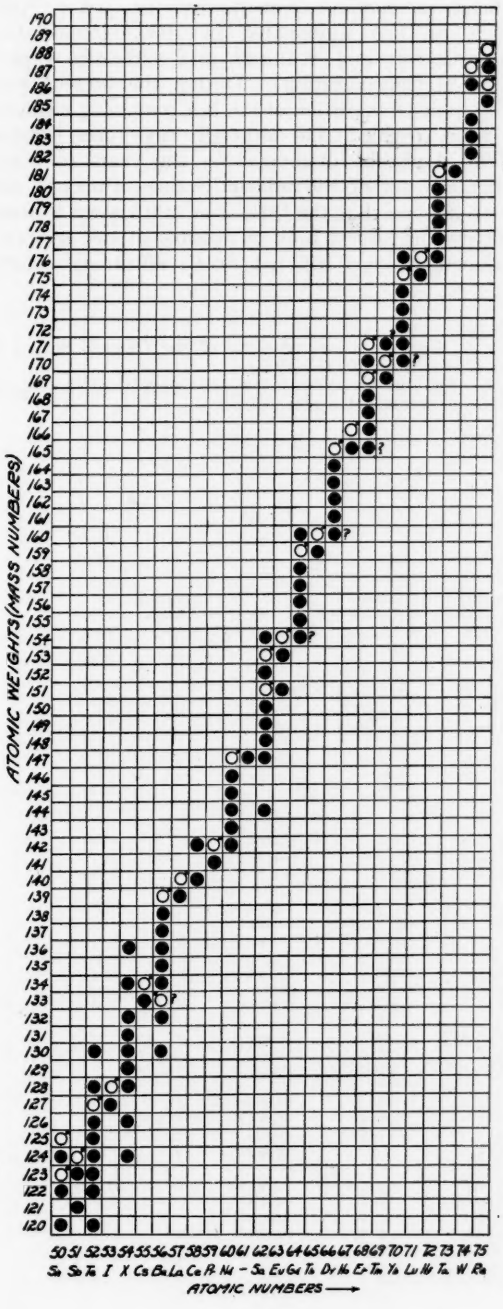

FIGURE 3

Against this, no doubt, the argument will be made that the practical atomic weight takes into consideration the abundance of each particular isotope. However, this point is not valid, since the abundance and also stability of isotopes, being nuclear properties, have nothing to do with the periodic law. Even the

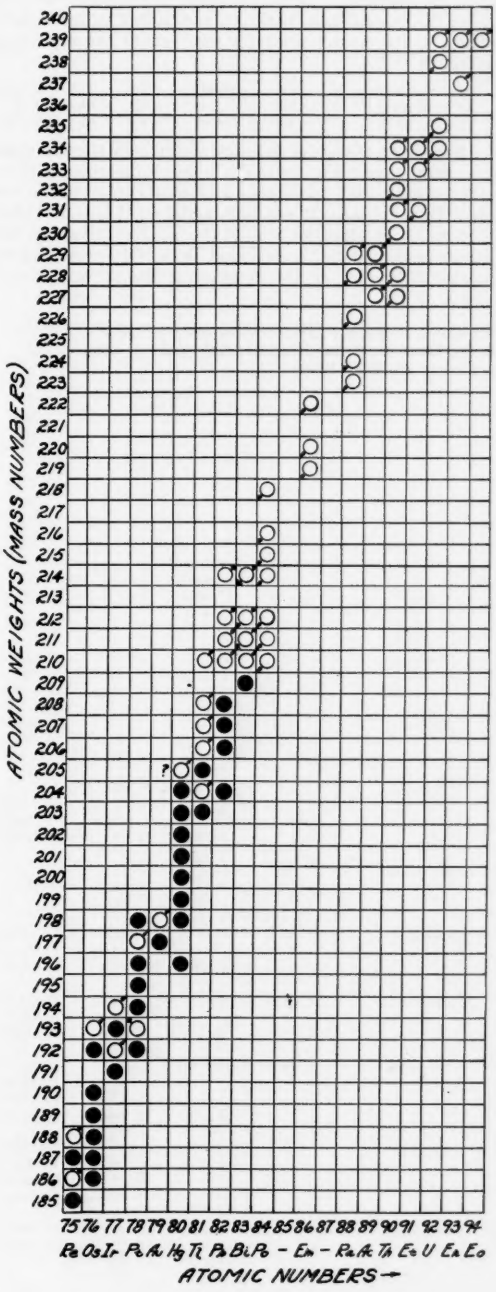

FIGURE 4

much more important point of the abundance or stability of elements among themselves *is not brought out* in the periodic system.

For particulars we refer the reader to Noddacks' abundance curves of the elements.[2] Here we would like to quote only their figures for three sets of neighboring elements showing their relative abundance in the earth's crust (in fractions of the total mass, multiplied by 10^6):

7	N	300	20	Ca	34000	81	Tl	0.00085
8	O	490000	21	Sc	0.75	82	Pb	8.0
9	F	270	22	Ti	58000	83	Bi	0.034

Furthermore in some cases of radioactive elements, the abundance changes with time. For instance, now protoactinium (91) is rarer than radium (88), but in past geological periods it was more abundant than the latter;[3] similarly actinium (89) is now about as abundant as polonium (84), but in the future will become rarer and rarer, owing to the more rapid decay of actinouranium, the mother substance of the actinium series, as compared to uranium I.

[2] W. AND I. NODDACK, *Naturwissenschaften*, **18**, 757 (1930).
[3] A. V. GROSSE, *Phys. Rev.*, **42**, 565 (esp. p. 569) (1932); *J. Phys. Chem.*, **38**, 487 (1934).

In the years following Aston's original discovery the number of established isotopes has continuously grown, especially recently since the discovery of artificial radioactive elements by the Joliot-Curies (which we had anticipated in 1932,[4] immediately after Cockroft and Walton's first successful experiments on transmutation). During the present year the isotopic composition of the last remaining elements has been revealed, and although new rarer isotopes will no doubt be discovered in the years to come, particularly among the radioactive ones, it may be now safe to assume that the little over 400 known isotopes represent the largest bulk of possible atomic species,* so that new ones will not *finally* affect our conclusion.

[4] A. V. GROSSE, *Chem. Bulletin* of the Chicago Section of Amer. Chem. Soc., **20**, 15 (1933).
* See also the discussion below on the natural limit of the number of isotopes of a given element.

TABLE 1
ISOTOPES OF THE ELEMENTS*
(AS OF DECEMBER, 1936)

Atomic Numbers	*Elements*	*Symbols*	*Individual Symbols of Isotopes*	*Mass Numbers*	*Physical Atomic Weights* $O^{16} = 16.0000$	*Packing Fractions* $\times 10^4$	*Isotopic Abundance in % of Total*	*Half-life, T† Stable?, ≃1 M.*	*Nature of Emitted Particles*	*Remarks*
0	Neutron	*n*		1	1.0085	+85			β^-?	Note 1
1	Hydrogen	H	H^1	1	1.00807	+80.7	99.98	Stable	...	
			D	2	2.01423	+71.1	0.02	Stable	...	
			T	3	3.01610	+54	10^{-1}?	Art.		
2	Helium	He		3	3.01699	+56.6	...	Art.		
				4	4.00336	+ 8.4	100	Stable	...	
			Ra-He	6?			Art.	≃1 s		
3	Lithium	Li		5?			?			
				6	6.01614	+26.9	7.9	Stable		
				7	7.01694	+24.2	92.1	Stable		
			Ra-Li	8	8.0185	+23.1	Art.	0.5 s	β^-	
4	Beryllium	Be		8?			Art.	Unstable	...	
				9	9.0135	+15.0	100	Stable	...	
				10?			Art.	Unstable	β^-?	
5	Boron	B		10	10.0146	+14.6	20.6	Stable		
				11	11.0111	+10.1	79.4	Stable		
			Ra-B	12	12.0176	+14.7	Art.	0.02 s	β^-	
6	Carbon	C	Ra-C	11	11.0136	+12.4	Art.	21 m	β^+	
				12	12.0037	+ 3.0	99.3	Stable	...	
				13	13.0069	+ 5.0	≃0.7	Stable	...	
7	Nitrogen	N	Ra-N	13	13.0095	+ 7.3	Art.	10.0 m	β^+	
				14	14.0076	+ 5.4	99.62	Stable	...	
				15	15.0053	+ 3.5	0.38	Stable	...	
			Ra-N	16	16.0069	+ 4.3	Art.	10.0 s	β^-	
8	Oxygen	O	Ra-O	15	15.0085	+ 5.7	Art.	2.1 m	β^+	
				16	16.0000	+ 0.00	99.76	Stable	...	
				17	17.0040	+ 2.3	0.04	Stable	...	
				18	18.0065	+ 3.6	0.20	Stable	...	
9	Fluorine	F	Ra-F	17	17.0077	+ 4.5	Art.	1.2 m	β^+	
				19	19.0000	+0.0 ± 1	100	Stable	...	
			Ra-F	20			Art.	12 s	β^-	
10	Neon	Ne		20	19.9986	− 0.7	90.0	Stable	...	
				21			0.27	Stable	...	
				22	21.9985	− 0.7	9.73	Stable	...	
			Ra-Ne	23			Art.	40 s	β^-	
11	Sodium	Na	Ra-Na	22			Art.	>½ a	β^+	
				23			100	Stable	...	
			Ra-Na	24			Art.	14.8 h	β^-	

TABLE 1 (*Continued*)

Atomic Numbers	*Elements*	*Symbols*	*Individual Symbols of Isotopes*	*Mass Numbers*	*Physical Atomic Weights* $O^{16} = 16.000$	*Packing Fractions* $\times 10^4$	*Isotopic Abundance in % of Total*	*Half-life, T† Stable?, ≃1M.*	*Nature of Particle*	*Remarks*
12	Magnesium	Mg		24	23.9938	− 2.6	77.4	Stable	...	
				25			11.5	Stable	...	
				26			11.1	Stable	...	
			Ra-Mg	27			Art.	10 m	β^-	
13	Aluminium	Al	Ra-Al	26			Art.	7 s	β^+	
				27	26.9909	− 3.0	100	Stable	...	
			Ra-Al	28			Art.	2.3 m	β^-	
			Ra-Al	29			Art.	11 m	β^-?	
14	Silicon	Si	Ra-Si	27			Art.	6 m	β^+?	
				28	27.9860	− 5.0	89.6	Stable	...	
				29	28.9864	− 4.7	6.2	Stable	...	
				30	29.9845	− 5.2	4.2	Stable	...	
			Ra-Si	31			Art.	2.5 h?	β^-	
15	Phosphorus	P	Ra-P	30			Art.	3 m	β^+	
				31	30.9844	− 5.0	100	Stable	...	
			Ra-P	32			Art.	14.5 d	β^-	
16	Sulfur	S		32	31.9812	− 6.0	≃97.0	Stable	...	
				33			≃ 0.8	Stable	...	
				34	33.9799	− 6.0	≃ 2.2	Stable	...	
			Ra-S	35			Art.	≃80 d	β^-?	
17	Chlorine	Cl	Ra-Cl	34			Art.	40 m	β^+	
				35	34.9796	− 5.8	76	Stable	...	
				37	36.9777	− 6.0	24	Stable	...	
			Ra-Cl	38?			Art.	37 m	β^-	
18	Argon	A		36	35.976	−6.6 ± 0.5	0.330	Stable	...	
				38	37.9753	− 6.5	0.05	Stable	...	
				40	39.9754	− 6.2	99.62	Stable	...	
			Ra-A	41			Art.	110 m	β^-	
19	Potassium	K		39			93.4	Stable	...	
				40		≃ −7	0.01	10^9 a	β^-	
				41			6.6	Stable	...	
			Ra-K	42			Art.	16 h	β^-	
20	Calcium	Ca		40			96.76	Stable	...	
				42		− 7.2	0.77	Stable	...	
				43			0.17	Stable	...	
				44			2.30	Stable	...	
			Ra-Ca	45			Art.	4 h	β^-?	
21	Scandium	Sc	Ra-Sc	42			Art.	3 h	β^+	
			Ra-Sc	43			Art.	4.4 h	β^+	
				45		≃− 7	100	Stable	...	
			Ra-Sc	46			Art.	>1 a	β^-	
22	Titanium	Ti		46			8.5	Stable	...	
				47			7.8	Stable	...	
				48		≃− 8	71.3	Stable	...	
				49			5.5	Stable	...	
				50			6.9	Stable	...	
23	Vanadium	V		51			100	Stable	...	
			Ra-V	52				3.7 m	β^-	
24	Chromium	Cr		50			4.9	Stable	...	
				52	51.948	−10 ± 3	81.6	Stable	...	
				53			10.4	Stable	...	
				54			3.1	Stable	...	
25	Manganese	Mn		55			100	Stable	...	
			Ra-Mn	56			Art.	2.5 h	β^-	
26	Iron	Fe		54			6.5	Stable	...	
				56		≃−10	90.2	Stable	...	
				57			2.8	Stable	...	
				58			0.5	Stable	...	
27	Cobalt	Co		57			0.16	Stable	...	
				59			99.84	Stable	...	
			Ra-Co	60			Art.	20 m	...	
28	Nickel	Ni		58	57.942	≃−10	67.5	Stable	...	
				60			27.1	Stable	...	
				61			1.7	Stable	...	
				62			3.8	Stable	...	
			Ra-Ni	63			Art.	100 m		
				64			0.9	Stable	...	
			Ra-Ni	65			Art.	3 h	β^-	

TABLE 1 (*Continued*)

Atomic Numbers	*Elements*	*Symbols*	*Individual Symbols of Isotopes*	*Mass Numbers*	*Physical Atomic Weights* $O^{16} = 16.0000$	*Packing Fractions* $\times 10^4$	*Isotopic Abundance in % of Total*	*Half-life, T† Stable?, ≃ 1M.*	*Nature of Emitted Particles*	*Remarks*
29	Copper	Cu		63			68	Stable	...	
			Ra-Cu	64			Art.	12.8 h	β^+ and β^-	
				65			32	Stable	...	
			Ra-Cu	66			Art.	6 m	β^-	
30	Zinc	Zn		64	63.937	− 9.9	50.4	Stable	...	
				66			27.2	Stable	...	
				67			4.2	Stable	...	
				68			17.8	Stable	...	
				70			0.4	Stable	...	
31	Gallium	Ga		69		≃ − 9.8	61.5	Stable	...	
			Ra-Ga	70			Art.	23 h	β^+	
				71		≃ − 9.8	38.5	Stable	...	
			Ra-Ga	72			Art.	20 m	β^-	
32	Germanium	Ge		70			21.2	Stable	...	
				72			27.3	Stable	...	
				73		≃ − 7.7	7.9	Stable	...	
				74			37.1	Stable	...	
				76			6.5	Stable	...	
33	Arsenic	As		75	74.934	−8.8 ± 1.5	100	Stable	...	
			Ra-As	76			Art.	26 h	β^-	
34	Selenium	Se		74			0.9	Stable	...	
				76			9.5	Stable	...	
				77			8.3	Stable	...	
				78	77.938	− 8.0	24.0	Stable	...	
				80	79.941	−7.3 ± 2	48.0	Stable	...	
				82			9.3	Stable	...	
			Ra-Se	?			Art.	35 m	β^-	
35	Bromine	Br		79	78.929	−9.0 ± 1.5	50.6	Stable	...	
			Ra-Br	80			Art.	4.2 h	β^-	
				81	80.926	−8.6 ± 1.5	49.4	Stable	...	
			Ra-Br	82			Art.	18 m	β^-	
			Ra-Br	?			Art.	35 h	β^-	
36	Krypton	Kr		78	77.926	−9.4 ± 2	0.42	Stable	...	
				80	79.926	−9.1 ± 2	2.45	Stable	...	
				82	81.927	−8.8 ± 1.5	11.79	Stable	...	
				83	82.927	−8.7 ± 1.5	11.79	Stable	...	
				84	83.928	−8.6 ± 1.5	56.85	Stable	...	
				86	85.929	−8.2 ± 1.5	16.70	Stable	...	
37	Rubidium	Rb		85		≃ − 8.2	72.7	Stable	...	
				86				10^9 a	β^-	
				87		≃ − 8.2	27.3	Stable	...	
38	Strontium	Sr		84			0.5			
				86			9.6	Stable	...	
				87		≃ − 8.2	7.5	Stable	...	
				88			82.4	Stable	...	
39	Yttrium	Y		89			100	Stable	...	
			Ra-Y	90			Art.	70 h	β^-	
40	Zirconium	Zr		90			48	Stable	...	
				91		≃ − 7	11.5	Stable	...	
				92			22	Stable	...	
			Ra-Zr	93			Art.	40 h	β^-?	
				94		≃ − 7	17	Stable	...	
				96			1.5	Stable	...	
41	Niobium	Nb		93	92.926	≃ − 8	100	Stable	...	
42	Molybdenum	Mo		92			14.2	Stable	...	
				94			10.0	Stable	...	
				95			15.5	Stable	...	
				96			17.8	Stable	...	
				97			9.6	Stable	...	
				98	97.946	− 5.5	23.0	Stable	...	
			Ra-Mo	99			Art.	36 h	β^-?	
				100	99.945	− 5.5	9.8	Stable	...	
			Ra-Mo	101			Art.	30 m	β^-?	
43	.....			99						Note 2
				101						

TABLE 1 (*Continued*)

Atomic Numbers	*Elements*	*Symbols*	*Individual Symbols of Isotopes*	*Mass Numbers*	*Physical Atomic Weights* $O^{16} = 16.0000$	*Packing Fractions* $\times 10^4$	*Isotopic Abundance in % of Total*	*Half-life, T† Stable?, ≃ 1M.*	*Nature of Emitted Particles*	*Remarks*
44	Ruthenium	Ru		96			5	Stable	...	
				99			12	Stable	...	
				100			14	Stable	...	
				101		≃ − 6	22	Stable	...	
				102			30	Stable	...	
			Ra-Ru	103			Art.	40 s	β^-?	
								100 s		
				104			17	Stable	...	
			Ra-Ru	105			Art.	11 h	β^-?	
								75 h		
45	Rhodium	Rh		101			99.9	Stable		
				103		≃ −5.7	0.1	Stable	...	
								44 s	β^-	
			Ra-Rh	104			Art.	3.9 m	β^-	
46	Palladium	Pd		102			0.8	Stable	...	
			Ra-Pd	103			Art.	60 h	β^+?	
				104			9.3	Stable	...	
				105			22.6	Stable	...	
				106			27.2	Stable	...	
			Ra-Pd	107		≃ −5.5	Art.	12 h	β^-?	
				108			26.8	Stable	...	
			Ra-Pd	109			Art.	15 m	β^-?	
				110			13.5	Stable	...	
			Ra-Pd	111			Art.	3 m	β^-?	
47	Silver	Ag		107			52.5	Stable	...	
			Ra-Ag	108		≃ −5.3	Art.	2.3 m	β^-	
				109			47.5	Stable	...	
			Ra-Ag	110			Art.	22 s	β^-	
48	Cadmium	Cd		106			1.4	Stable	...	
				108			1.0	Stable	...	
				110			12.8	Stable	...	
				111			13.0	Stable	...	
				112		≃ −6.5	24.2	Stable	...	
				113			12.3	Stable	...	
				114			28.0	Stable	...	
				115			Art.	3.5 h	β^-	
				116			7.3	Stable	...	
49	Indium	In		113			4.5	Stable	...	
			Ra-In	114		≃ −7.4	Art.	13 s	β^-	
				115			95.5	Stable	...	
			Ra-In	116			Art.	54 m	β^-	
50	Tin	Sn		112			1.1	Stable	...	
				114			0.8	Stable	...	
				115			0.4	Stable	...	
				116			15.5	Stable	...	
				117			9.1	Stable	...	
				118			22.5	Stable	...	
				119			9.8	Stable	...	
				120	119.912	−7.3 ± 2	28.5	Stable	...	
				122			5.5	Stable	...	
			Ra-Sn	123			Art.	18 m	β^-?	
				124			6.8	Stable		
			Ra-Sn	125			Art.	8 m	β^-?	
51	Antimony	Sb		121			56	Stable	...	
				123		≃ 6	44	Stable	...	
			Ra-Sb	124		≃ −6	Art.	2.5 d	β^-	
52	Tellurium	Te		120			Very rare	Stable	...	
				122			2.9	Stable	...	
				123			1.6	Stable	...	
				124			4.5	Stable	...	
				125		≃ −5	6.0	Stable	...	
				126			19.0	Stable	...	
			Ra-Te	127			Art.	45 m	β^-	
				128			32.8	Stable	...	
				130			33.1	Stable	...	
53	Iodine	I		127	126.932	−5.3	100	Stable	...	
			Ra-I	128			Art.	25 m	β^-	
54	Xenon	Xe		124			0.08	Stable	...	
				126			0.08	Stable	...	
				128			2.30	Stable	...	
				129			27.13	Stable	...	
				130			4.18	Stable	...	
				131			20.67	Stable	...	
				132			26.45	Stable	...	
				134	133.929	−5.3 ± 2.0	10.31	Stable	...	
				136			8.79	Stable	...	

TABLE 1 (*Continued*)

Atomic Numbers	*Elements*	*Symbols*	*Individual Symbols of Isotopes*	*Mass Numbers*	*Physical Atomic Weights* $O^{16} = 16.0000$	*Packing Fractions* $\times 10^4$	*Isotopic Abundance % of Total*	*Half-life, T† Stable?, ≃1 M.*	*Nature of Emitted Particles*	*Remarks*
55	Cesium	Cs		133			100	Stable	....	
			Ra-Cs	134	132.933	−5 ± 2.0	Art.	1.5 h	β^-	
56	Barium	Ba		130			0.16	Stable	...	
				132			0.015	Stable	...	
			Ra-Ba	133			Art.	Stable	β^+?	
				134			1.72	Stable	...	
				135			5.7	Stable	...	
				136			8.5	Stable	...	
				137			10.8	Stable	...	
				138	137.916	−6.1 ± 2	73.1	Stable	...	
			Ra-Ba	139			Art.	80 m	β^-?	
57	Lanthanum	La		139			100	Stable	...	
			Ra-La	140			Art.	1.9 d	β^-	
58	Cerium	Ce		140			89	Stable	...	
				142			11	Stable	...	
59	Praseodymium	Pr		141			100	Stable	...	
			Ra-Pr	142			Art.	19 h	β^-	
			Ra-Pr	?			Art.	5 m	β^-	
60	Neodymium	Nd		142			36	Stable	...	
				143			11	Stable	...	
				144			30	Stable	...	
				145			5	Stable	...	
				146			18	Stable	...	
			Ra-Nd	147			Art.	1 h	β^-	
61				147				Stable	...	Product of Nd^{147} Note 3
62	Samarium	Sa		144			3	Stable	...	One of them α-active
				147			17	Stable	...	
				148			14	Stable	...	
				149			15	Stable	...	
				150			5	Stable	...	
			Ra-Sa	151			Art.	2 d	β^-	
				152			26	Stable	...	
			Ra-Sa	153			Art.	40 m	β^-	
				154			20	Stable	...	
63	Europium	Eu		151			50.6	Stable	...	
				153			49.4	Stable	...	
			Ra-Eu	154			Art.	9.2 h	β^-	
64	Gadolinium	Gd		154?			Very rare?	Stable	...	Product of Eu^{154}
				155			21	Stable	...	
				156			23	Stable	...	
				157			17	Stable	...	
				158			23	Stable	...	
			Ra-Gd	159			Art.	7 h	β^-	
				160			16	Stable	...	
65	Terbium	Tb		159			100	Stable	...	
			Ra-Tb	160			Art.	3.9 h	β^-	
66	Dysprosium	Dy		160?			Very rare?	Stable	...	Product of Tb^{160}
				161			22	Stable	...	
				162			25	Stable	...	
				163			25	Stable	...	
				164			28	Stable	...	
			Ra-Dy	165			Art.	2.5 h	β^-	
67	Holmium	Ho		165			100	Stable	...	
			Ra-Ho	166			Art.	35 h	β^-	
68	Erbium	Er		165			36	Stable	...	
				166			Very rare?	Stable?	...	Product of Ho^{166}
				167			24	Stable	...	
				168			30	Stable	...	
			Ra-Er	169			Art.	12 h	β^-	
				170			10	Stable	...	
			Ra-Er	171			Art.	7 m	β^-	
69	Thulium	Tm		169			100	Stable	...	
			Ra-Tm	170			Art.	≃120 d	β^-	
				171?			Very rare?	Stable	...	Product of Er^{171}

Changes from about −6 at La (57) to about −3 at Lu (71).

TABLE 1 (*Continued*)

Atomic Numbers	*Elements*	*Symbols*	*Individual Symbols of Isotopes*	*Mass Numbers*	*Physical Atomic Weights* $O^{16} = 16.0000$	*Packing Fractions* $\times 10^4$	*Isotopic Abundance in % of Total*	*Half-life, T† Stable?, ≃ 1 M.*	*Nature of Emitted Particles*	*Remarks*
70	Ytterbium	Yb		170?		Changes from about −6 at La (57) to about −3 at Lu (71).	Very rare?	Stable	...	Product of Tm^{170}
				171			9	Stable	...	
				172			24	Stable	...	
				173			17	Stable	...	
				174			38	Stable	...	
			Ra-Yb	175			Art.	3.5 h	β^-	
				176			12	Stable	...	
71	Lutecium	Lu		175			100	Stable	...	
			Ra-Lu	176?			Art.	6–7 d	β^-	
			Ra-Lu	?			Art.	4 h	β^-	
72	Hafnium	Hf		176			5	Stable	...	
				177			19	Stable	...	
				178		≃ − 3	28	Stable	...	
				179			18	Stable	...	
				180			30	Stable	...	
			Ra-Hf	181			Art.	Long	β^-?	
73	Tantalum	Ta		181	180.928	− 4	100	Stable	...	
74	Tungsten	W		182			22.6	Stable	...	
				183			17.3	Stable	...	
				184	184.00	≃ 0	30.2	Stable	...	
				186			29.9	Stable	...	
			Ra-W	187?			Art.	1 d	β^-?	
75	Rhenium	Re		185			38.2	Stable	...	
			Ra-Re	186			Art.	85 h	β^-	
				187	186.981	−1 ± 2	61.8	Stable	...	
			Ra-Re	188			Art.	20 h	β^-	
76	Osmium	Os		186			1.0	Stable	...	
				187			0.6	Stable	...	
				188			13.4	Stable	...	
				189			17.4	Stable	...	
				190	189.98	−1 ± 2	25.1	Stable	...	
				192	191.98	−1 ± 2	42.5	Stable	...	
			Ra-Os	193			Art.	40 h	β^-?	
77	Iridium	Ir		191			38.5	Stable	...	
			Ra-Ir	192			Art.	68 d	β^-?	
				193			61.5	Stable	...	
			Ra-Ir	194			Art.	19 h	β^-	
78	Platinum	Pt		192			0.8	Stable	...	
				193			Art.	49 m	β^+	
				194			30.2	Stable	...	
				195			35.3	Stable	...	
				196			26.6	Stable	...	
			Ra-Pt	197			Art.	14.5 h	β^-	
				198			7.2	Stable	...	
79	Gold	Au		197			100	Stable	...	
			Ra-Au	198			Art.	2.7 d	β^-	
80	Mercury	Hg		196			0.10	Stable	...	
				198			9.89	Stable	...	
				199			16.45	Stable	...	
				200	200.016	+0.8 ± 2	23.77	Stable	...	
				201			13.67	Stable	...	
				202			29.27	Stable	...	
				203			≃0.006	Stable	...	
				204			6.85	Stable	...	
			Ra-Hg	205			Art.	40 h	β^-?	
81	Thallium	Tl		203	203.037	+1.8 ± 2	29.4	Stable	...	
			Ra-Tl	204			Art.	97 m	β^-?	
				205	205.037	+1.8 ± 2	70.6	Stable	...	
			Ra-Tl	206			Art.	4 m	β^-?	
			AcC″	207			Nat. rad.	4.76 m	β^-	
			ThC″	208			Nat. rad.	3.1 m	β^-	
			Ra-C″	210			Nat. rad.	1.32 m	β^-	
82	Lead	Pb		204			1.52	Stable	...	
			RaG	206	206.00 ± 0.01	0.0 ± 0.5	28.03	Stable	...	
			AcD	207			20.40	Stable	...	
			ThD	208	208.00 ± 0.01	0.0 ± 0.5	50.05	Stable	...	
			RaD	210			Nat. rad.	19 a	β^-	
			AcB	211			Nat. rad.	36.0 m	β^-	
			ThB	212			Nat. rad.	10.6 h	β^-	
			RaB	214			Nat. rad.	26.8 m	β^-	

TABLE 1 (*Continued*)

Atomic Numbers	*Elements*	*Symbols*	*Individual Symbols of Isotopes*	*Mass Numbers*	*Physical Atomic Weights* $O^{16} = 16.0000$	*Packing Fractions* $\times 10^4$	*Isotopic Abundance in % of Total*	*Half-life, T† Stable?, ≃ 1M.*	*Nature of Emitted Particles β-?*	*Remarks*
83	Bismuth	Bi		209		$\simeq +0.5 \pm 1$	100	Stable	...	
			RaE	210			Nat. rad. and art.	4.9 d	β^-	
			AcC	211			Nat. rad.	2.16 m	α and β^-	
			ThC	212			Nat. rad.	60.5 m	α and β^-	
			RaC	214			Nat. rad.	19.7 m	α and β^-	
84	Polonium	Po	RaF	210	210.01 ± 0.01	$\simeq +0.5 \pm 0.5$	Nat. rad. and art.	140 d	α	
			AcC′	211			Nat. rad.	ca. $5 \cdot 10^{-3}$ s	α	
			ThC′	212			Nat. rad.	$1 \cdot 10^{-7}$ s	α	
			RaC′	214			Nat. rad.	ca. 10^{-6} s	α	
			AcA	215			Nat. rad.	$2 \cdot 10^{-3}$ s	α	
			ThA	216			Nat. rad.	0.14 s	α	
			RaA	218			Nat. rad.	3.05 m	α	
85	.....?	...								Note 4
86	Emanation	Em	An	219			Nat. rad.	3.92 s	α	
			Tn	220			Nat. rad.	54.5 s	α	
			Rn	222	222.04 ± 0.01	$\simeq +1.8 \pm 0.5$	Nat. rad.	3.825 d	α	
87	.....?	...								Note 5
88	Radium	Ra	AcX	223			Nat. rad.	11.2 d	α	
			ThX	224			Nat. rad.	3.64 d	α	
			RaI	226	226.05 ± 0.01	$\simeq +2.2 \pm 0.5$	Nat. rad.	1590 a	α	
			$MsTh_1$	228			Nat. rad.	6.7 a	α	
			A^{229}_{88}	229			Art.	1 m	β^-	
89	Actinium	Ac	AcI	227			Nat. rad.	13.5 a	β^-	
	Ekalanthanum	(El)	$MsTh_2$	228			Nat. rad.	6.13 h	β^-	
			B^{229}_{89}	229			Art.	12 m	β^-	
90	Thorium	Th	RaAc	227			Nat. rad.	18.9 d	α	
			RaTh	228			Nat. rad.	1.90 a	α	
			Io	230			Nat. rad.	$8.3 \cdot 10^4$ a	α	
			UY	231			Nat. rad.	24.6 h	β^-	
			ThI	232	232.070		Nat. rad.	$1.8 \cdot 10^{10}$ a	α	
				233			Nat. rad.	30 m	β^-	
			UX_1	234			Nat. rad.	24.5 d	β^-	
91	Ekatantalum	Et	Pa	231	231.073 ± 0.01	$\simeq +3.2 \pm 0.5$	Nat. rad.	32000 a	α	
			A^{233}_{91}	233			Art.	2.5 m	β^-	
			UX_2 or Bv	234			Nat. rad.	1.14 m	β^-	
			UZ	234			Nat. rad.	6.7 h	β^-	
92	Uranium	U	UII	234			Nat. rad.	$3 \cdot 10^5$ a	α	
			AcU	235	235.084 ± 0.01	$\simeq 3.6 \pm 0.5$	Nat. rad., 0.4%	$4.10a^3$	α	
			UI	238	238.088 ± 0.01	$\simeq +3.7 \pm 0.05$	Nat. rad., 99.6%	$4.45 \cdot 10^9$ a	α	
				239?			Art.	10 s	β^-	
				239?			Art.	40 s	β^-	
93	Ekarhenium	En		237?			Art.	2.2 ± 2 m	β^-	Note 6
				239?			Art.	16 ± 1 m	β^-	
94	Ekaosmium	Eo		239?			Art.	59 ± 2 m	β^-	Note 6

† a = years, d = days, h = hours, m = minutes, s = seconds.

* The data given in the table (and also Figures 1–4) were obtained mainly from the following sources:

A. On *stable isotopes;* from
(1) The "Report of the Commission on Atoms of the International Union of Chemistry," **1936.**
(2) F. W. Aston's book, "Mass spectra and isotopes," **1933.**
(3) O. Hahn's yearly report, *Ber.*, **69, A5** (1936).

B. On *artificial radio-isotopes;* from
(1) F. Rasetti's book "Elements of nuclear physics," **1936.**
(2) G. v. Hevesy and H. Levi's publication in *Kgl. Danske Videnskabernes Selskab., Math.-fys. Meddelelser. XIV,* **5** (1936), particularly on those of the rare-earth elements.
(3) O. Hahn's review in *Ber.*, **69,** A217 (1936).
N. B. It should be stressed that the assignment of specific mass numbers to the artificial radio-isotopes is open to question in a number of cases and may have to be changed in future. Furthermore the possibility that the same isotope may have two (or more) different decay periods should also be taken into consideration.

C. On *natural radio-isotopes;* from
(1) Last report of the "International Committee of radioactive elements and their constants," *Phil. Mag.*, (7), **12,** 609 (1931).
Additional data from the following recent publications were included:
(1) E. B. ANDERSEN, *Zeit. phys. Chem.*, **32B,** 237 (1936).
(2) A. J. DEMPSTER, *Nature*, **138,** 120, 201 (1936); *Phys. Rev.*, **50,** 98, 186 (1936).
(3) W. BLEAKNEY AND M. S. SAMPSON, *ibid.*, **50,** 456, 732 (1936).

TABLE 1 (*Concluded*)

(4) W. BLEAKNEY AND CO-WORKERS, *Phys. Rev.*, **50**, 545 (1936).
(5) J. P. BLEWETT, *ibid.*, **49**, 641 (1936).
(6) C. J. BLASEFIELD AND E. POLLARD, *ibid.*, **49**, 889 (1936).
(7) J. M. CORK AND E. O. LAWRENCE, *ibid.*, **49**, 788 (1936).
(8) W. A. FOWLER, L. A. DELSASSO, AND C. C. LAURITSEN, *ibid.*, **49**, 561 (1936).
(9) C. B. MADSEN, *Nature*, **138**, 722 (1936).
(10) R. NAIDU, *ibid.*, **137**, 578 (1936).
(11) A. O. NIER, *Phys. Rev.*, **50**, 1041 (1936).
(12) A. H. SNELL, *ibid.*, **49**, 555 (1936).
(13) S. N. VAN VOORHIS, *ibid.*, **49**, 876 (1936); **50**, 895 (1936).

NOTES FOR TABLE 1

1. Calculated value for the half-life of the neutron = about 1 month, see H. A. BETHE AND R. F. BACHER, *Rev. Mod. Phys.*, **8**, 201 (1936).
2. Probable stable products of Mo^{99} and Mo^{101}. The discovery of the element announced in 1924 has not yet been confirmed.
3. Probable stable product of Nd^{147}. The discovery of the element, announced in 1926, has not yet been confirmed.

4 & 5. Elements supposedly discovered by the magneto-optic method in 1931 and 1929, respectively, as yet without any confirmation by orthodox methods.

6. The discovery of elements 93 and 94 was announced by E. Fermi and his co-workers (*1*) in 1934. Originally M. S. Agruss and the present writer (*2*) objected to Fermi's interpretation of his results, because *first*—elements 93 and 94 should have, according to the Periodic Law, other chemical properties (*2, 3*) than those described by Fermi and *second*—his reactions were also given by element 91 (*4*). To test the identity with element 91 the writer suggested (*2*) its most characteristic analytical reaction, namely its coprecipitation with zirconium phosphate (*5*). After E. Fermi (*6*) (and also O. Hahn (*7*)) showed that his products were not precipitated with zirconium phosphate the writer's objections were withdrawn (*4*). In the meantime the careful investigations of O. Hahn and L. Meitner (*7, 8, 9, 10, 11*) have shown that the actual chemical reactions of the new elements, particularly of element 93, are in full agreement with the properties, predicted by us, so that now the arguments based on the periodic law are supporting Fermi's claim and his original inaccurate reactions may be considered superseded by Hahn's work.

The existence of elements 95—ekairidium, 96—ekaplatinum, and 97—ekagold, suggested by O. Hahn (*11, 10, 9*), although possible, requires further knowledge of their chemical properties before final conclusions may be reached. Their presently assumed chemical character, *i. e.*, homologues of iridium, platinum, and gold, contradicts the requirements of N. Bohr's (*12*) theory of a second group of very similar, "second rare earths" elements shortly after uranium (*3, 13*) (where every additional electron will be bound in the 5 f level).

(1) E. FERMI, *Nature*, **133**, 898 (1934); *Proc. Roy. Soc., London*, **146A**, 483 (1934).
(2) A. V. GROSSE AND M. AGRUSS, *Phys. Rev.*, **46**, 241 (1934).
(3) A. V. GROSSE, *J. Am. Chem. Soc.*, **57**, 440 (1935).
(4) A. V. GROSSE AND M. S. AGRUSS, *ibid.*, **57**, 438 (1935).
(5) A. V. GROSSE, *Ber.*, **61**, 237 (1928).
(6) E. FERMI, private communication.
(7) O. HAHN AND L. MEITNER, *Naturwissenschaften*, **23**, 37 (1935).
(8) O. HAHN AND L. MEITNER, *ibid.*, **23**, 230 (1935).
(9) O. HAHN, L. MEITNER, AND F. STRASSMANN, *ibid*, **23**, 544 (1935).
(10) O. HAHN, L. MEITNER, AND F. STRASSMANN, *Ber.*, **69**, 905 (1936).
(11) O. HAHN, *ibid.*, **69A**, 217 (1936).
(12) N. BOHR, *Z. f. Physik*, **9**, 1 (1922); *Ann. d. Physik*, **71**, 228 (1923).
(13) See in particular TA-YOU-WU AND S. GOUDSMIT, *Phys. Rev.*, **43**, 496 (1933).

TABLE 2
MEAN ATOMIC WEIGHTS

Atomic Number	*Symbol of Element*	*Mean Atomic Weight*	*Increase from Element to Element**	*Atomic Number*	*Symbol of Element*	*Mean Atomic Weight*	*Increase from Element to Element**	*Atomic Number*	*Symbols of Element*	*Mean Atomic Weight*	*Increase from Element to Element**
0	*n*	1.0	1.0	32	Ge	73.0	2.5	64	Gd	157.0	2.5
1	H	2.0	2.3	33	As	75.5	2.3	65	Tb	159.5	3.0
2	He	4.3	2.7	34	Se	77.8	2.7	66	Dy	162.5	3.0
3	Li	7.0	2.0	35	Br	80.5	1.7	67	Ho	165.5	2.5
4	Be	9.0	2.0	36	Kr	82.2	3.8	68	Er	168.0	2.0
5	B	11.0	1.0	37	Rb	86.0	0.3	69	Tm	170.0	3.0
6	C	12.0	2.5	38	Sr	86.3	3.2	70	Yb	173.0	2.5
7	N	14.5	2.0	39	Y	89.5	3.2	71	Lu	175.5	3.0
8	O	16.5	2.2	40	Zr	92.7	0.3	72	Hf	178.5	2.5
9	F	18.7	2.8	41	Cb	93.0	3.9	73	Ta	181.0	3.4
10	Ne	21.5	1.5	42	Mo	96.9	3.1?	74	W	184.4	2.1
11	Na	23.0	2.5	43	..	100?	1.3?	75	Re	186.5	2.8
12	Mg	25.5	2.0	44	Ru	101.3	1.4	76	Os	189.3	3.2
13	Al	27.5	1.5	45	Rh	102.7	3.8	77	Ir	192.5	2.5
14	Si	29.0	2.0	46	Pd	106.5	2.0	78	Pt	195.0	2.5
15	P	31.0	2.5	47	Ag	108.5	3.2	79	Au	197.5	3.0
16	S	33.5	2.5	48	Cd	111.7	2.8	80	Hg	200.5	5.6
17	Cl	36.0	2.7	49	In	114.5	4.4	81	Tl	206.1	2.9
18	A	38.7	1.8	50	Sn	118.9	3.8	82	Pb	209.0	2.2
19	K	40.5	2.3	51	Sb	122.7	2.3	83	Bi	211.2	2.5
20	Ca	42.8	1.2	52	Te	125.0	2.5	84	Po	213.7	3.3?
21	Sc	44.0	4.0	53	I	127.5	2.5	85	..	217?	3.3?
22	Ti	48.0	3.5	54	X	130.0	3.5	86	Em	220.3	2.7?
23	V	51.5	0.8	55	Cs	133.5	1.4	87	..	223?	3.0
24	Cr	52.3	3.2	56	Ba	134.9	4.6	88	Ra	226.0	2.0
25	Mn	55.5	0.8	57	La	139.5	1.5	89	Ac	228.0	2.7
26	Fe	56.3	2.4	58	Ce	141.0	0.5	90	Th	230.7	2.0
27	Co	58.7	3.2	59	Pr	141.5	3.0	91	Et	232.7	3.8
28	Ni	61.9	2.6	60	Nd	144.5	2.5?	92	U	236.5	1.5?
29	Cu	64.5	2.5	61	..	147.?	2.8?	93	En	238.?	...
30	Zn	67.0	3.5	62	Sa	149.8	2.9	94	Eo	239.?	...
31	Ga	70.5	2.5	63	Eu	152.7	4.3				

* The *mean* increase from element to element equals $\simeq 2$ for light nuclei (up to P), increases to $\simeq 2.5$ for elements between Mn and Sn and reaches the value 2.9 for the very heavy nuclei.

All reliably known atomic species, both stable and naturally or artificially radioactive are listed in Table 1 and Figures 1–4, and from them we derive the values of the *mean atomic weights* (or mean mass numbers). Listing these in ascending order (see Table 2) we see immediately that the *mean atomic weight of an element always increases with its nuclear charge and that, therefore, the row of increasing mean atomic weights is identical with the sequence of increasing nuclear charges*, so that both may be used for the exact formulation of the periodic law.

The four exceptions, mentioned at the beginning, now realign themselves as follows:

$$_{18}A\ (38.7) \longrightarrow\ _{19}K\ (40.5)$$
$$_{27}Co\ (58.7) \longrightarrow\ _{28}Ni\ (61.9)$$
$$_{52}Te\ (125.0) \longrightarrow\ _{53}I\ (127.5)$$
$$_{90}Th\ (230.7) \longrightarrow\ _{91}Et\ (232.7)$$

In the present language of nuclear physics this empirical rule means that the sum of the number of protons and the mean number of neutrons that combine with them to form *all possible isotopes* of an element always increases with the number of protons in its nucleus.

A natural limit to the number of possible isotopes of an element is set by radioactivity. The data of Figure 1 show (a particular example being the classical case of Al, Si, and P) that if for a given number of protons in the nucleus (Z), the number of neutrons *increases* beyond certain limits, a *neutron* changes into a *proton* by *electron* emission, leading to an element of higher atomic number ($Z + 1$). On the other hand, if they *decrease* beyond certain limits a *proton* changes into a *neutron*, emitting a *positron*, thereby decreasing the atomic number by one, as illustrated in Table 3. (An equivalent change can also take place, particularly among the heaviest nuclei, through the emission of an α-particle.)

TABLE 3

Atomic Numbers	Individual Atomic Weights	M^{-K}_{-3}	M^{-K}_{-2}	M^{-K}_{-1}	M^{-K}	M	M^{+K}	M^{+K}_{+1}	M^{+K}_{+2}	M^{+K}_{+3}
$Z-1$		$\delta\beta^+$	•	•	•	•	•	$\varphi\beta^-$		
Z			$\delta\beta^+$	•	•	•	•	•	$\varphi\beta^-$	
$Z+1$				$\delta\beta^+$	•	•	•	•	•	$\varphi\beta^-$

$p \xrightarrow{\beta+} n$—Intranuclear Stabilization—$n \xrightarrow{\beta-} p$

A rigorous theoretical explanation of these facts should be possible when the laws of interaction between nuclear particles are more definitely known.

WHY NOT IONS BEFORE ELECTRONS?

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WOULD not the introduction of the ionic theory between the discussions of the atomic and electronic theories, rather than after both, as is commonly done, simplify and clarify much of our first semester chemistry work? Classroom trial is one obvious test of value. Results here at Washington have been wholly favorable. At least, in connection with the rest of our procedure, the shift appears permanently desirable.

There was no difficulty encountered in presenting the ionic theory that early. Differences in *amount* of charge on ions were merely designated as such and indicated in the conventional manner with plus and minus signs, without reference to the unitary character of the charges.

We begin our study of chemistry, using water to illustrate the properties of matter. Electrolysis of water leads us to distinguish elements from compounds. When we begin to investigate electrolytes we are already familiar, from that example, with the transfer of electric charge and the accompanying chemical changes. Therefore the difference in properties between charged and uncharged atoms does not seem strange. We proceed with our analysis from compounds through ions to the structure of atoms. The electron theory must account, as it did historically, for the difference in properties between ion and uncharged atom as well as for the differences between kinds of atoms.

In the meantime we recognize from the earliest possible moment that, in the solutions with which we deal for the most part, ions, rather than molecules, are the significant units. We write equations in the ionic form from the start, at least wherever the difference is of any significance, and avoid having to retrace our steps to rewrite in that form in the study of salts, acids, and bases, or later in understanding ionic equilibria. Early familiarity with ions especially facilitates the approach to the modern view of acid-base equilibria.

Is the change more than the recognition of the central position of the ionic condition as that most commonly met in chemical reaction?

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ABSTRACTS

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KEEPING UP WITH CHEMISTRY

Molds as chemical reagents. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **124**, 4 (May, 1937).—We are familiar with the use of molds for the preparation of acids. Until 1920 yeast and bacteria were the chief agents for the production of ethyl and butyl alcohol, lactic, acetic, and propionic acids, glycerol, acetone, and others. Since then molds have entered the field. Probably more than half of the citric acid produced in this country originates from the action of different strains of the black mold, *Aspergillus niger*, on sugar. The production of gluconic acid from sugar by different molds has also been known since the latter part of the last century, but only recently has it been made to produce high yields. Lactic acid is being produced today by use of the *Rhizopus* or "bread mold group". In addition to acids a variety of other substances are being produced by molds grown in sugar solutions. Among them is ergosterol or provitamin D.

G. O.

The growth of the artificial resin industry in the U. S. A. See this title under Scientific Reviews and Bibliographies; Tabulations of Scientific Data.

The oxygen industry. See this title under Scientific Reviews and Bibliographies; Tabulations of Scientific Data.

The adulteration of food. J. R. NICHOLLS. *Sci. Progr.*, **31**, 258–67 (Oct., 1936).—Adulteration is the intentional addition to an article, for purposes of gain or deception, of any substance or substances, the presence of which is not acknowledged in the name under which the article is sold. The addition of one article to another is not always adulteration; but a declaration of such addition may be necessary. Where any such addition is for the purpose of concealing poor quality, or where the article added is injurious to health, an offence is committed.

There is no widespread adulteration today. Eighty years ago, there were few articles of consumption which were not extensively subjected to adulteration. The nature of the adulterants at that time is shown by the following table.

Food	*Adulterants*
Bread	Copper sulfate, pipe clay, alum
Flour	Calcium sulfate, bone earths, powdered flints
Milk and cream	Flour, treacle, sheep's brains, chalk
Pepper	Clay
Gin	Cayenne

Other materials which were decidedly injurious to health were also employed, *viz.*, *Cocculus indicus*, copper arsenite, lead chromate, lead oxide, orpiment, Prussian blue, bronze powders, cinnabar.

Conditions today are very different. The number of violations is scarcely above five per cent. Milk seems to be the greatest offender.

General Forms of Adulteration

Water—An excess of water means that the public pays for water at the price of the article. Many foodstuffs have a legal limit for water content, and hence violations of the law can be readily determined.

Ash and Sand—Sand is objectionable and usually means an inadequate cleaning of the natural material.

Preservatives—Preservatives in foods are prohibited with the exception of sulfur dioxide and benzoic acid. The term "preservatives" does not include sugar, salt, and vinegar.

Metallic Impurities—Certain metals may unavoidably contaminate foodstuffs. Acid material is unsuitable for keeping in tin-lined cans and the use of solder for sealing cans is to be avoided if there is likelihood of its dissolving in the contents of the can.

Mites, Weevils, etc.—If due care is not taken in storing foodstuffs they may become infested with insects.

Staleness—A stale or rancid article sold as fresh would involve an offense under the Food and Drugs Act.

Labeling—Any article which is suitable for food may be offered for sale and the question of adulteration does not arise if the description of the article represents its true nature. A misdescription or a failure to disclose an essential ingredient may result in a charge. Certain foods, *e. g.*, condensed milk, must be labelled in a prescribed manner and conform to certain standards.

Particular Forms of Adulteration

Specific examples of adulteration may be found to some extent in connection with any of the following commodities, *viz.*: bread and flour, pearl barley, cornflower, arrowroot, chewing gum, honey, butter, cheese, meat, eggs, coffee, spirits, vinegar, spices, rice, oatmeal, sago, sugar, jam, milk, cream, margarine, oils and fats, fish, tea, cocoa, beer, lemon juice.

Such adulteration as exists today is of a relatively minor character. Manufacturers and retailers endeavor to obtain and to retain a high reputation on the quality of their products. Gross adulteration is easy of detection, and the profits from small frauds are meager and more than counterbalanced by loss of reputation through publicity if legal action is taken. The efforts of medical officers, of health and sanitary inspectors, who condemn unsound food, of public analysts, who check adulteration, and of reputable manufacturers who serve the public have together resulted in the nations' food being of a higher standard of purity today than at any stage of our history. R. K. C.

Technological importance of reclaimed rubber. D. S. PLUMB. *Chem. & Met. Eng.*, **44**, 194–7 (April, 1937).—Reclaimed rubber is a product obtained by chemical treatment of vulcanized scrap rubber and contains crude rubber, chemically combined sulfur, oils, tars, fillers, and other materials. Its chemical treatment in the reclaiming plants renders it capable of being processed like crude rubber. New sulfur must be added for vulcanization. It can be used in almost every rubber product. Addition of reclaim to a rubber compound generally lowers the value of the physical properties of the compound. There is usually a straight-line relationship between the decrease in physical properties and the percentage of reclaim used.

A study made on the use of reclaim in automobile tires led to the conclusions that it is feasible in the tread, economically advantageous in the carcass and definitely superior in the bead.

In the event of war the United States would be largely dependent on reclaim rubber. Reclaim supplied approximately one-fifth of the consumption of rubber in the United States in 1935.

J. W. H.

Corn proteins offer industrial possibilities. J. F. WALSH. *Chem. & Met. Eng.*, **44**, 190 (April, 1937).—A wide range of substances for industrial uses has been developed from corn proteins.

The proteins constitute about ten per cent. by weight of the corn and are first isolated as process waste in the manufacture of starch. This process waste or "gluten" is about fifty per cent. protein. Three general types of industrial proteins are obtained from it.

A carbohydrate free protein is used in the plastics field as a base, filler, reactive component in cellulose derivatives, natural and synthetic resins, and raw material for the preparation of amino acids.

The second group is made up of carbohydrate, alcohol-soluble, free proteins and differs from the former type in that they are soluble in dilute alkalies and insoluble in aqueous alcohol solutions. They are used as a filler, a component of phenolic resins and as a base in alkaline coating solutions.

The third and most important group constitutes the aqueous-alcohol-soluble prolamines known as "zein".

It is white, odorless, tasteless, amorphous and similar in many ways to shellac, casein, and cellulose esters. It is highly suitable for use as a base in plastic and organic solvents and dilute aqueous alkaline coating solutions. It can be hydrolyzed to a wide variety of amino acids. J. W. H.

Modern hydrogenations. F. BRIERS. *Sch. Sci. Rev.*, **18,** 314–20 (Mar., 1937).—The term hydrogenation, which implies catalytic reduction, was introduced by Sabatier. Hydrogenation was first applied industrially to the hardening of liquid fats and oils for the soap, fat, and edible oil industries. In these operations nickel, reduced by hydrogen from its salts, is used as catalyst. Other modern technical hydrogenation processes involve the synthesis of ammonia, methanol, higher alcohols, and fuel and lubricating oils. Like the hydrogenation of edible oils, these processes lend themselves to careful control, the variable factors being temperature, pressure, catalyst, and reaction time. The Bergius process, introduced in 1913, for the hydrogenation of coal to yield fuel and lubricating oils, is of considerable importance in countries having coal deposits but no petroleum. Researches by Fischer and Tropsch during the last fifteen years have led to the process of converting carbon monoxide by hydrogenation into lubricating oils, gasoline, and fuel gas. S. W.

Hormone activity in plants. E. BARTON-WRIGHT. *Sch. Sci. Rev.*, **18,** 401–12 (Mar., 1937).—A brief review of the chemistry and the physiology of the several plant hormones. The article contains twelve references. S. W.

Recent history of the sterol group. I. C. DOREE. *Sch. Sci. Rev.*, **18,** 337–46 (Mar., 1937).—A review.

Some chemical reactions of glass. V. DIMBLEBY. *Sch. Sci. Rev.*, **18,** 330–6 (Mar., 1937).—So used are we to the everyday service which glass gives us that the idea of it being chemically active appears unlikely. However, slight reactions may take place between glass and substances with which it is kept in contact, and even after many years of study, the subject still offers much scope for investigation.

Present glassware used for scientific work is satisfactory from the standpoint of thermal and chemical stability, but earlier workers encountered difficulties with glassware, which were mainly due to their lack of resistance to alkali. Chemical resistance in glass is not demanded by the scientist only, but milk bottles, food jars, containers for medicine, beverages, etc., must all stand up to repeated sterilization.

The recent use of glass in building has created a new problem of weathering. When glass is stored under atmospheric conditions, sometimes a whitish deposit appears on the surface, which under the microscope are seen to be crystalline. It is alkaline to phenolphthalein. The first step in the weathering is the hydration of the alkali, silicates, or borates, with the liberation of free alkali. The latter reacts with carbon dioxide of the atmosphere, forming alkali carbonates. The dissolving out of the alkali leaves the glass less alkaline and therefore more resistant to attack. Weathering resistance is chiefly due to the composition of the glass, but other factors, such as the surface conditions, method of annealing, etc., play a part. The growth of lichens, as on old cathedral glass, has been shown to aid decomposition. The presence of hydrogen sulfide and sulfur dioxide is known to produce deposits on optical glass containing barium or lead. S. W.

Leadleaf paint. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **123,** 3 (Apr., 1937).—Metallic lead is being used as the main ingredient of a protective paint. Lead has been used heretofore in the oxide form, but "Metalead" paint is made from thin lead foil broken up into fine flakes which when spread out in the form of a paint film form a "leaf." Linseed oil has not proved a satisfactory vehicle to hold the lead. Present vehicles include the new synthetic resins and Chinawood oil or tung and mixtures containing phenolics such as Beckacite, Durez, or Bakelite. The new paint is offered as an undercoater or primer on structural framework. As offered to manufacturers, the lead is in paste form with ten per cent. vehicle and weighs about forty pounds to the gallon. Metalead paint is being used as a competitor of red lead. It cannot compete with aluminum in cost. G. O.

Vaulting the void. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **123,** 3–4 (Apr., 1937).—The possibility of wide-spread industrial application of a high-vacuum distillation and sublimation seems almost fantastic. The so-called "molecular" high vacuum methods have served during the past few years as an effective research tool producing an interesting series of products including dyes from crude dyestuffs, delicate hormones from body fluids, quick-drying varnish polymers from fish oils or ordinary cottonseed oil. In molecular vacuum distillation there is a vacuum chamber containing heated and cooled surfaces of great area within an inch or so of each other. The mixture flows in a thin film down the heated surface, its molecules vaporize off and in "one jump" arrive almost instantly at the cooling surface where they are condensed. The process is most conveniently conducted as a continuous operation and has been adapted to fractional distillation. It may also be used to separate mixtures which, because of their constant boiling point, cannot be separated by ordinary methods of distillation, the differences of vapor pressure being the chief factor. Molecular distillation is especially adapted for treating heat-sensitive substances, such as butter, to extract both flavor ingredients and vitamins without injury either to them or to the stripped butter fat left behind. A partially hydrogenated cod-liver oil vitamin concentrate prepared by this method is reported to be free from all flavor and entirely suitable for incorporation in foods. Molecular distillation removes substantially all of the non-polymers but none of the polymers. Short-path molecular distillation is also applicable to solids. Some of the solids so isolated include caffeine from coffee, quinine from cinchona bark, madder from madder root. Various dyes are purified in this manner. A dirty dark-brown rosin may be refined to a pure white powder. As a research tool, molecular distillation required small glass apparatus. Suitable demountable equipment is now under construction. G. O.

Accomplishments and future of chemical physics. H. C. UREY. *Ind. Eng. Chem., News Edition,* **15,** 190–1 (1937).—A summary of technical developments of the first quarter of the century. The fixation of nitrogen and the hydrogenation of coal are called the two most important. The economic importance of rayon and artificial wool is discussed. The prediction is made that in the future it will be necessary for man to live on the energy arriving from the sun. This will mean close coöperation between biologist and chemist. A. A. V.

Chemical research. I. LANGMUIR. *Ind. Eng. Chem., News Edition,* **15,** 188–9 (1937).—The author discusses types of research carried on in industry and emphasizes the importance of fundamental research conducted in commercial laboratories. The prediction is made that future development will be in the field of application of new physical methods to the studies of the familiar properties of matter. A. A. V.

SCIENTIFIC REVIEWS AND BIBLIOGRAPHIES; TABULATIONS OF SCIENTIFIC DATA

Cohesive forces in metals. N. F. MOTT. *Sci. Progr.*, **31,** 414–23 (Jan., 1937).—In the last few years great advances have been made from the theoretical side in our understanding of the metallic state by the application of quantum mechanics to the behavior of free electrons in metals. The work of Sommerfeld, Pauli, and Heisenberg in this field are well known.

A theory of the metallic bond must make possible the calculation of quantities which can be compared with experimental values. Of these one of the most important is the energy of the metal. From this can be deduced at once the heat of sublimation; if the energy can be obtained for different values of the interatomic distance the compressibility may be deduced, and also the specific volume under zero pressure. If the energy can be calculated for a series of different crystal structures the structure for which the energy is lowest should be the one which the metal is actually found to have.

The energy of the crystal will then be made up of the following terms: (1) the mutual electrostatic potential energy of the positive ions; (2) the electrostatic energy of the free electrons in the field of the ions; (2) the mutual electrostatic potential energy of the electrons with one another; (4) the kinetic energy of the electrons.

The assumption that, even at the absolute zero of temperature, electrons have kinetic energy, is, of course, a familiar one, even in

the earliest forms of the quantum theory, as for instance in Bohr's theory of the hydrogen atom, in which the orbital electrons were assumed to be in continuous motion. The kinetic energy of the conduction electrons in metals plays, as we shall see, an important part in metallic cohesion.

Metals such as copper or silver may thus be regarded as an array of hard spheres (the ions Cu^+ or Ag^+) embedded in a sea of negative charge, the negative charge forcing the hard spheres together. This is the reason why these metals take up the cubic closed-packed structure, which is one of the structures in which the greatest number of spheres can be packed into a given volume. The purely electrostatic energy, on the other hand, may be shown to be lowest in the body-centered structure, which is that of the alkalies.

The electrostatic forces discussed here give energies of the order of the binding energy of metals, about 100 kcal. per gram atom. In order to account for the crystal structure of metals and alloys, it is necessary to estimate the very much smaller difference between the energies resulting from the various possible structures. As H. Jones has shown it is possible to account for the well-known Hume-Rothery rule of alloy structures. This rule may be stated as follows. Alloys such as Cu-Zn, Cu-Al, Cu-Sn, etc., form a series of different structures (phases) as the concentration of the second-named component is changed. If one ascribes to copper one valence electron, to zinc two, to aluminum three, and to tin four, the boundaries of the phases occur approximately at the same electron-atom ratio for the different alloy systems. For instance, the α-phase which has the same face-centered structure as copper, becomes unstable when the ratio of electrons to atoms exceeds a value varying between 1.35 and 1.4; the β-phase (body-centered cubic) is stable in a narrow range of compositions about the electron-atom ratio 3/2; and the complicated γ-structure is formed when the electron-atom ratio is 21/13.

At present, calculations of the cohesive forces have only been made for copper, silver, and the alkali metals; the theory has yet to be extended to metals like zinc or aluminum, which contribute more than one electron per atom, and to the more complicated transition metals such as nickel. The foregoing theoretical discussion of the phase diagrams of alloy systems is, moreover, of a very qualitative nature; the precise energy differences between the different phases has not been calculated; and there are many types of phase diagram which have not been treated at all. Nevertheless, it seems likely that investigations of the kind described here will in the course of time lead to an understanding of the nature of the metallic bond in the more important metals and alloys. R. K. C.

Photoelectric cells and their application in the chemical industry. R. SUHRMANN. *Chem.-Ztg.*, **61**, 245–7 (March 20, 1937).—A survey. L. S.

Progress in the field of analytical chemistry due to the use of complex compounds. E. TSCHIRCH. *Chem.-Ztg.*, **61**, 225–8 (Mar. 13, 1937).—A survey. Complex compounds in qualitative analysis. *A*. Microchemical reactions. Detection of potassium as potassium, copper, lead nitrate; uranyl acetate complex of sodium. *B*. Adsorption reactions. Chinalizarin (1,2,5,8-tetraoxyanthraquinone) as a sensitive test for magnesium; basic lanthanum acetate as a color reaction for acetates. *C*. Preventive reactions. (Such reactions are involved when the normal course of a chemical reaction leading to insoluble, colored, or gaseous product is prevented by the addition of certain compounds.) Complex zirconium fluoride ion for the detection of fluorides; detection of free acid and basic constituents in aluminum compounds. *D*. Color and precipitation reactions. Copper salt of benzoin oxime; diethizon complexes. Complex compounds in organic chemistry. Oxyquinoline complexes; metal pyridine cyanide compounds; bismuth pyragallol complexes. Thirty-two references. L. S.

The growth of artificial resin industry in the U. S. A. R. E. VOGEL. *Chem.-Ztg.*, **61**, 165–7 (Feb. 20, 1937).—A review dealing with plastics, urea resins, cellulose derivatives, artificial rubbers, and artificial resins for the oil lacquer industry. L. S.

The oxygen industry. V. WAESER. *Chem.-Ztg.*, **61**, 213–6 (Mar. 10, 1937); 236–7 (Mar. 17, 1937).—A review covering historical, general, economic, and statistical data; the manufacture by means of chemical methods, electrolysis, liquid air, ozone, and "per" compounds; and the utilization of oxygen, ozone, and "per" compounds. Ninety-five references are cited. L. S.

The utilization of air. C. W. P. HEYLANDT. *Chem.-Ztg.*, **61**, 10–1 (Jan. 2, 1937).—Various uses of liquid air are described. L. S.

The manufacture of caffeine-free coffee. W. ROSELINS. *Chem.-Ztg.*, **61**, 153–5 (Feb. 17, 1937).—A description. L. S.

HISTORICAL AND BIOGRAPHICAL

A forgotten, 4000 year-old-alloy of copper and arsenic. WILHELM WITTER. *Chem.-Ztg.*, **61**, 149 (Feb. 13, 1937).—Two daggers which were discovered in Germany and which are at least four thousand years old were analyzed and found to consist of an alloy of copper and arsenic. Literature references are cited showing that similar alloys had been used in various other countries several thousand years ago. L. S.

Death of Professor Sydney Young. ANON. *Nature*, **139**, 705 (Apr. 24, 1937).—Professor Sydney Young died at Bristol on April 8 at the age of seventy-nine years. During the years 1882 to 1887 he collaborated with Sir William Ramsay in researches on evaporation and dissociation and the thermal properties of liquids. After his appointment to the chair of chemistry at Bristol in 1887, Professor Young undertook a long series of investigations on the generalization of van der Waals, the determination of critical volume and density, and the boiling points of different liquids at equal pressures. With the aid of a special still head which he himself devised, Professor Young prepared liquids of exceptionally high purity and made a thorough study of the lower boiling fractions of American petroleum. In 1903 he became professor of chemistry at Trinity College, Dublin. From 1921 to 1926 he was president of the Royal Irish Academy. M. E. W.

Ole Rømer's and Fahrenheit's thermometers. K. MEYER (NÉE BJERRUM). *Nature*, **139**, 585–6 (Apr. 3, 1937).—Dr. Meyer does not agree with Professor J. Newton Friend (*Nature*, **139**, 395–6 (March 6, 1937)) that Ole Rømer used a freezing mixture in fixing the zero of his thermometer. She cites Rømer's *Adversaria* to show that he used as his lower fixed point the temperature of melting snow or crushed ice. In his reply to Dr. Meyer (*ibid.*, **139**, 586 (Apr. 3, 1937)), Dr. Friend states that he does not believe it "a pure coincidence that Rømer's zero corresponds to the eutectic temperature of ice and salt—a mixture that was already well known in Boyle's time." M. E. W.

Professor Amé Pictet, 1857–1937. G. B. *Nature*, **139**, 661 (Apr. 17, 1937).—The great Swiss chemist, Amé Pictet died on March 12. He studied under Marignac, Kekulé, and Anschütz. During his long career as professor of chemistry at Geneva, he synthesized nicotine, laudanosine, papaverine, maltose, and lactose. M. E. W.

The historical development of the hardening of fats. See this title under Scientific Reviews and Bibliographic Tabulations of Scientific Data.

FOREIGN CHEMICAL AND EDUCATIONAL CONDITIONS

Scientific research in Spain. C. S. GIBSON. *Nature*, **139**, 719–20 (Apr. 24, 1937).—The Society for the Protection of Science and Learning has received gratifying evidence that scientific investigation and literary research are by no means at a standstill in Spain. Recent issues of the *Anales de Física y Química*, the *Revista de Filología Española*, and the *Anuario del Observatorio de Madrid* contain original work which has been made possible by the *Casa de la Cultura* of Valencia founded by the Ministry of Education. M. E. W.

RECENT BOOKS

QUALITATIVE ANALYSIS AND CHEMICAL EQUILIBRIUM. *T. R. Hogness*, Associate Professor of Physical Chemistry, University of Chicago, and *Warren C. Johnson*, Associate Professor of Chemistry, University of Chicago. Henry Holt and Co., New York City, 1937. xii + 417 pp. 27 figs. 23 × 14 cm. $2.75.

Among the several recent attempts at presenting the subject of qualitative analysis as a typical application of the principles of theoretical or physical chemistry, this text distinguishes itself by a number of commendable features. Half of the book is devoted to an elementary but clear and detailed discussion of those portions of physical chemistry which are directly illustrated by, and applied in, qualitative analysis (properties of solids, liquids and solutions—reaction velocity and chemical equilibrium—weak acids and bases—solubility product—colloids—hydrolysis—complex ions—amphoteric substances—oxidation and reduction). Teachers of qualitative analysis will be surprised at the enormous amount of information of the kind usually imparted by word of mouth only which is contained in this text. Answers are provided for most questions, even the most naïve ones, with which teachers of the subject are always faced. The numerous problems worked out with unusual wealth of detail at the end of each chapter, and the appendix on mathematical operations contribute to make the book an efficient educational tool.

The theory of the solubility product as given by the authors is particularly satisfactory, although, even in an elementary text, salt effects on solubilities and on ionization constants should not be omitted. The presentation of the subject of oxidation-reduction by means of equilibrium constants of half-reactions instead of single-electrode potentials is a distinct pedagogical advance. It is to be regretted, however, that a short discussion of these potentials has not been included, and that the connection between the arbitrary choice of equilibrium constant for the half-reaction $H_2 \rightarrow 2H^+$ and the arbitrary choice of zero potential for the normal hydrogen electrode is not mentioned. In spite of their opinion to the contrary, we feel that the authors could have added considerable strength to their book by including the, after all, so simple theory of acids and bases initiated by Brønsted.

The experimental portion of the book also contains appreciably more information than most elementary texts of this kind. The method of analysis involves the use of small samples (3 milliliters of "unknown" with the concentration of each ion not greater than 0.02 molar), and offers undeniable advantages. Procedures and preliminary experiments are described with unusual care.

Altogether, this book is, without question, one of the best solutions so far proposed for the difficult educational problem of providing teachers and students with a simple but adequate and consistent transition between elementary and advanced chemistry.

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QUANTITATIVE ANALYSIS. *Willis Conway Pierce*, Assistant Professor of Chemistry, University of Chicago, and *Edward Lauth Haenisch*, Assistant Professor of Chemistry, Villanova College. John Wiley and Sons, Inc., New York City, 1937. xi + 412 pp. 14 figs. 15 × 23 cm. $3.00.

In this text it is the avowed purpose of the authors to correlate and stress the various objectives sought in the teaching of quantitative analysis. These objectives include acquainting the student with the more common analytical procedures and their applications, the development of a certain amount of technic and the development of comprehension of the theoretical principles underlying analytical methods, ability in performing the calculations involved in analyses, an awareness of sources of error, and an appreciation of the precision and accuracy which can be expected in a determination.

The book is written for a first course in quantitative analysis and contains more than enough material for a year's work. However, the arrangement is such that it may be easily used as a text in a one-semester course. This flexibility is gained in part by dividing the book into four sections. Part I comprises general directions, and also deals with the balance, methods of weighing, weight calibration, and, finally, with precision, errors and significant figures.

The authors favor studying volumetric methods first, and, therefore, Part II deals with these methods. Here, after treatment of methods and apparatus, neutralization is discussed. As is the general procedure in this text there is first a brief description of neutralization methods and simplified theory, then their stoichiometry in which the significance of the concept of the milliequivalent is clearly stressed, and finally laboratory procedures. Methods of analysis are given for sodium hydroxide solution, acetic acid, vinegar, oxalic acid, soda ash, and organic nitrogen by the Kjeldahl-Gunning method. Oxidation-reduction methods involving permanganate, iodine, ceric ions and dichromate are next treated. Procedures are given for iron in solution (Jones reductor), iron ore (Zimmermann-Reinhardt), pyrolusite (available oxygen), nitrite, stibnite, sulfur in steel, copper in solution, and copper ore. A separate chapter on the electrochemical theory of oxidation-reduction processes gives a clear-cut presentation based on sound physical chemistry. The section ends with a consideration of precipitation methods including the methods of Mohr, Volhard, and Fajans.

Part III treats of gravimetric analysis, and opens with a chapter on the theory of precipitation presented largely in conformity with the work of Kolthoff. Then, after discussion of general operations and calculations, analytical procedures are given for soluble chloride, iron, sulfur, sulfur in pyrites, phosphorus in phosphoric acid, and in a mineral; also a complete limestone analysis.

Part IV deals with special methods and opens with a chapter on the theory and practice of analysis by electrodeposition, in which procedures for the analysis of a copper-nickel solution and of a brass are given. The next chapter deals briefly with the theory of electrometric titrations and gives procedures for acid-base titrations with the hydrogen and quinhydrone electrode; also an oxidation-reduction titration. The next chapter is devoted to colorimetric methods. After a brief consideration of theory and apparatus, methods are given for manganese in steel, titanium, and ammonia in water. The last chapter gives a short concise introduction to the bibliography and journal literature of analysis, and illustrates clearly how *Chemical Abstracts* can be used to secure information not to be found in textbooks. Finally, the appendices present information on the use of exponents and logarithms, and also treat the subject of hydrolysis. Adequate tables of equilibrium constants and five-place logarithms are given.

Special pains appear to have been taken to make an adequate, well-correlated presentation of theory and procedure in this text, which makes it both clear and effective. To this end the most difficult theory has been segregated, numerous questions have been introduced, and many problems have been included, typical problems being carefully worked out, in order to indicate principles and methods; some problems are stated with answers, others without answers. The detailed analytical procedures are interspersed with frequent references to adjacent notes which supply much pertinent information. If this text is used intelligently, even the less able student starting quantitative analysis should achieve acceptable results, and this is much to be desired as it serves to give the student a respect for, and confi-

dence in, analytical chemistry. Throughout the book the sources of error and probable precision are laudably stressed and this should help greatly in developing, particularly in the better students, the ability for judging the real significance of the results of an analysis. The authors appear to have made a real contribution to the teaching of elementary quantitative analysis.

W. WALKER RUSSELL

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ATOMIC SPECTRA AND THE VECTOR MODEL. Vol. I: Series Spectra; Vol. II: Complex Spectra. *A. C. Candler*, Sometime Scholar of Trinity College, Cambridge. Two Volumes. First Edition, Cambridge University Press, London, 1937. viii + 237 pp. (Vol. I), vi + 279 pp. (Vol. II). 354 figs. 13.5 × 21.5 cm. Set, $8.50.

The chapter headings in the first volume are as follows: Hydrogen Atom, Alkali Doublets, Alkaline Earths, Absorption Spectra, Zeeman Effect, Paschen-Back Effect, Atomic Magnetism, Stark Effect, The Periodic System, and Doublet Laws. In these chapters there are discussed such topics as Landé's interval rule, the spinning electron and the vector model, intensity rules, the Stern-Gerlach method for determining magnetic moments of atoms and the paramagnetism of ions. The chapter on the periodic system contains sections on valency, covalency, electronic structures and X-rays.

The second volume contains a discussion of each of the following topics: Displaced Terms, Combination of Several Electrons, Short Periods, Long Periods, Rare Earths, Intensity Relations, Sum Rules and (*jj*) Coupling, Series Limit, Hyperfine Structure, Quadripole Radiation, and Fluorescent Crystals. In the chapters dealing with the different periods the characteristics of individual spectra are discussed, and tables given of the more important terms.

Aside from the application of the vector model, the presentation of the observations on spectra is largely from the point of view of the experimental spectroscopist. The Bohr theory is discussed briefly and there is one short section on wave mechanics in which no mention is made of the Schroedinger equation or of the relation of the Schroedinger function to the Bohr orbital model.

The author has dealt rather briefly with topics which involve the mechanism of production of spectral lines. Thus there is no mention of metastable states. It also seems that in the energy-level diagram for caesium (p. 39) it might be better to label the lowest level 6*s* in accordance with the electronic structure given in the table on pages 195–6. The same criticism would apply to the energy-level diagrams for calcium and mercury, and to those given on pp. 177–8, Vol. I.

Probably the use of "inductive methods free from the heavy mathematics of the quantum mechanics" (quoted from the advertisement on the cover) will appeal to a number of readers, and for those who wish to obtain a summary of our present knowledge of atomic spectra, apart from the relation of this information to theoretical considerations, the present treatise should prove of material assistance.

SAUL DUSHMAN

RESEARCH LABORATORY
GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

ORGANIC CHEMISTRY. *Frank C. Whitmore*, Dean of the School of Chemistry and Physics and Research Professor of Organic Chemistry, Pennsylvania State College. D. Van Nostrand Co., Inc., 250 Fourth Avenue, New York City, 1937. x + 1080 pp. 14 × 21.5 cm. $7.50 net.

The English-speaking countries are supplied with a wealth of good elementry organic textbooks, intended for instructional use in colleges and universities, but generally of too limited scope to serve as adequate reference works for advanced students. It is therefore gratifying to find a book designed, according to its author, "for practising organic chemists—and for students who have pursued organic chemistry for at least a year—a text of advanced character for those already possessing reasonable knowledge and experience in organic chemistry."

Within its covers is packed a very great amount of information, accurate and strictly up-to-date. Some saving of space has been effected by omission of many topics found in more elementary texts, and also by the use of readily understood abbreviations in the descriptive portions. The type is, nevertheless, large and easy to read. The printing and binding are good, but the book is not free from typographical errors. These seem to be the most numerous in the section on heterocyclic compounds.

The order of arrangement of subject matter is the conventional one—aliphatic compounds (six hundred fourteen pages), alicyclic compounds (one hundred eighty-two pages), and heterocyclic compounds (eighty-two pages). It will be noted that considerably more space has been devoted to the aliphatics "in keeping with the present trend toward aliphatic chemistry, especially in the British and American Industry." The section on heterocyclic compounds is larger than in most books of this character, and the treatment of the derivatives of aromatic hydrocarbons, while relatively short, is nevertheless adequate. The very complete subject index (one hundred twenty-one pages) is certainly a most desirable feature.

There are few paged references to the literature, and most of these are to the "Annual Reports of the Progress of Chemistry." It is more customary to find only the author's name and the date of publication of his article, since it is manifestly impractical in a text of this kind to make the documentation complete.

"The use of electronic conceptions has been definitely limited to those cases in which ordinary structural formulas fail. In most processes of organic chemistry, the bond corresponds exactly to the effect of an electron pair, and nothing is achieved by substituting two dots for the conventional dash." The author's own ideas are liberally introduced in the numerous discussions of reaction mechanism.

"A deliberate attempt is made to explode what might be termed the fallacy of the homologous series," in which it is assumed that a study of two or three individuals will furnish a satisfactory picture of the reactions of a whole class of compounds. It has thus been necessary to consider in detail a rather large number of alcohols in order to demonstrate satisfactorily the effect of the substitution of alkyl groups upon their properties.

The author has succeeded well in writing a book that will be of considerable value, not only to students specializing in chemistry, but also to chemists not in academic life.

F. W. BERGSTROM

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MODERN-LIFE CHEMISTRY. *Frank O. Kruh*, Soldan High School, St. Louis, Missouri, *Robert H. Carleton*, Summit High School, Summit, New Jersey, and *Floyd F. Carpenter*, Stivers High School, Dayton, Ohio. Edited by *W. R. Teeters*, supervisor of physical and biological sciences, St. Louis Public Schools. J. B. Lippincott Co., Chicago, 1937. xxv + 734 pp. 359 figs. 13.4 × 19.3 cm. $1.80.

This book is a textbook in elementary chemistry designed for the upper secondary school level, and "offered in the belief that it will prove to be a positive contribution to the evolution of a truly functional course for high-school students." The book is rigorously constructed according to the Morrison unit-problem plan, the eleven units being entitled: Foundations of Chemistry; The Structure of Matter; Solutions and Near-Solutions; Chemical Action in Solution; Chemical Equations and Calculations; Sulfur and Its Compounds; The Halogens and the Periodic Classification; The Nitrogen Family; Mineralogy and Chemistry; Metallurgy and Chemistry; Organic Chemistry. The last two units are relatively long, occupying about one hundred pages each.

Each unit is built about a consistent plan. The unit assignment is defined and the problems listed. Each problem is "solved" by study of the "assimilative material for the unit" which consists of three parts, the assignment, the subject matter, and problem summary exercises for all. From three to six problems constitute a unit. Optional material follows, additional problem summary exercises, chemical arithmetic exercises, and topics for investigation. Concluding each unit is a unit recitation and test which is a list of general topics for oral or written recitation.

Two of the authors gained experience through writing an outstanding workbook, "Comprehensive Units in Chemistry" (F. F. Carpenter and R. H. Carleton, J. B. Lippincott Co., 1935), and many of the valuable pedagogical devices found in the workbook are also in the textbook. The book abounds in sound, useful chemistry presented in an interesting fashion. Each specialized part of the text has been read and criticized by an authority in the field.

Atomic structure is introduced at an early point (p. 93) and the basis for the remaining topics is thus established. Ions are developed from modified electronic structures, and not made an outgrowth of a study of electrolytic solutions. Both the Bohr and the Lewis-Langmuir theories are used in part to explain valence due to electron transfer or sharing. The ionic theory gives full credit to Arrhenius and carries the modern explanations of ions with fine balance, not becoming too involved in complications, or, on the other hand, assuming that no change or evolution has taken place recently.

Much material is included on many topics, leaving a fairly wide range for choice. One finds, for example, four pages devoted to the storage battery, an abundance of equations, some space given to crystals and the six main classes of crystals, many more names of persons than is customary in a book of this type. An outstanding feature of the book is the inclusion in parentheses of practically all the common radicals.

This book merits consideration by all chemistry teachers because of its modern approach, its effective organization, its teachableness, and fine illustrations.

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LABORATORY PRACTICE OF ORGANIC CHEMISTRY. *G. Ross Robertson*, Associate Professor of Organic Chemistry in the University of California at Los Angeles. The Macmillan Co., New York City, 1937. xii + 326 pp. 14 × 21 cm. $2.25.

This manual is intended to give an unusually extensive treatment of the principles underlying organic laboratory manipulations and, in contrast to the recent trend, to serve as the basis for a course in which preparative experiments, rather than small-scale or test-tube reactions, are emphasized. Enough experiments are included to meet the needs of a year course, with options for superior students. For the optional experiments reference is usually made to other manuals.

The book is divided into two nearly equal parts with numerous cross references in each. Part I consists of theoretical material and includes chapters on general laboratory instructions, temperature control, isolation and purification of liquids, washing and extraction, isolation and purification of solids, drying, solubility, sublimation, the phenomena of melting and freezing, recrystallization from solution, mass action and equilibrium, calculation of quantities of materials, organic acids and bases, the separation of substances from mixtures, and the use of the literature. References to the literature and to other manuals and texts are numerous. Part II contains the laboratory directions, a chapter on qualitative organic analysis and a chapter on introduction to organic research. Questions and problems are given at the end of each experiment and at the end of each chapter in Part I. The appendix includes necessary physical data and a summary of the quantities of reagents necessary in the various experiments.

The theoretical portion of this book is particularly to be commended. It is much more comprehensive than is usually found in organic manuals. Much of the material is based on applications of the phase rule. This probably represents duplication of some of the subject matter of elementary physical chemistry, but it is presented here in a form more suitable for organic application. The nature of this section is such that even graduate students should profit from some parts of it.

The laboratory experiments are fairly orthodox. The isolation of the diazonium inner salt from sulfanilic acid, the synthesis of α-hydroxy-α-methylbutyric acid, the preparation of propionaldehyde and the use of potassium carbonate and pyridine in the Perkin reaction are perhaps the most novel departures from the usual experiments. Quantities are given in moles rather than in grams and the concentration of solutions in normality rather than percentage. The frequent use of isopropyl ether seems a worthwhile innovation. In some cases the approximate yield which may be expected is given; in others this is omitted. The directions are for the most part simple and complete. Some of the space devoted to repeated instruction about the removal of paper from the stopcocks of separatory funnels before use might well be used for warnings about the toxicity of nitrobenzene, phenylhydroxylamine and phenylhydrazine and the disagreeable properties of benzyl chloride and benzalacetone. It would seem that a comprehensive treatment should contain a considerable amount of information about fractionating columns, but only the Hempel and Vigreux columns are mentioned. Stem corrections are explained, but no instructions are given for the determination of the average temperature of the exposed stem. In the chapter on literature mention is made of the fourth edition of Beilstein and "a few supplementary volumes" and Richter's "Lexikon" is described as paralleling Beilstein; from this the student might infer that Richter refers to the fourth edition of Beilstein.

Most of the other adverse criticisms that might be made concern matters of personal opinion. In the two pages devoted to the use of the literature it is obviously impossible to do more than mention the most important sources of information. The value of a skeleton course in qualitative organic analysis which can be covered in fourteen pages is debatable. The introduction to methods of research covers a little over two pages and actually states the type of advanced work allowed in the course, rather than containing information about methods of research. There are several statements in the book which might be questioned, but which are not important enough to mention here.

The book is written in an informal style which in general is satisfactory; however, the use of such expressions as "batch," "which see below" and "introduce in" seems unfortunate. In many cases current practice in nomenclature is ignored: "phenyl diazonium chloride," "tetraphenylpinacol," "magnesium phenyl bromide." While there is little danger of confusion in the use of these names it would seem preferable in teaching to use the standard nomenclature. For the same reason it seems that the directions for the experiments might well have followed more closely the conventions used in writing research papers. Only two typographical errors were noted.

All in all, this manual seems to contain features which will attract many teachers. Even those who do not plan to use it in their laboratory course will find it of interest.

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ZERO TO EIGHTY. *Akkad Pseudoman.* Scientific Publishing Company, Princeton, New Jersey, 1937. 15 × 23 cm. $3.00.

Two parts popularized physics, one part success story, one part romance, one part melodrama, one part adventure, one and a half parts sophomore philosophy, a pinch of H. G. Wells, with indiscriminate dashes of orange bitters, anise, and bath salts.

OTTO REINMUTH

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This important new text emphasizes theoretical aspects and close relationships between theory and laboratory practice, and approaches the subject from the physical chemistry point of view. It is designed for use in the usual college course in quantitative analysis. The number of determinations described is greater than can be accomplished in the average course in this subject; thus the teacher may select those best suited to the needs of his students.

Desha's

ORGANIC CHEMISTRY. The Chemistry of the Compounds of Carbon

By Lucius Junius Desha, Washington and Lee University. *International Chemical Series.* 729 pages, $3.75

Three definite departures from the conventional order and methods of presentation make this interesting new work stand out from the usual run of textbooks in organic chemistry. First, a distinctively original arrangement of subject matter, particularly in the parallel treatment of aliphatic and aromatic compounds. Second, the author sets out to develop principles, illustrated by descriptions of appropriate compounds, instead of the general practice of describing compounds with apparently incidental mention of principles. Third, the extensive use of the deductive method stimulates the student to instruct himself by applying general principles to predicting the properties and reactions of specific compounds.

Coghill and Sturtevant's

INTRODUCTION TO THE PREPARATION AND IDENTIFICATION OF ORGANIC COMPOUNDS

By Robert D. Coghill and Julian M. Sturtevant, Yale University. *International Chemical Series.* 223 pages, $1.75

In addition to the orthodox material on laboratory procedures and the preparation of organic compounds, this new manual offers a unique feature in the inclusion of a simplified system of qualitative organic analysis covering some 350 common substances, together with a description of the preparation of suitable derivatives from these compounds. The authors have found that qualitative organic analysis greatly increases the pedagogical value of the laboratory work. Wherever feasible, recent advances in this field have been included, particularly in the section on the preparation of derivatives. Another feature of this manual is the procedure of illuminating the laboratory directions with discussions of the chemistry involved in the preparations and identifications.

Sherwood's

ABSORPTION AND EXTRACTION

By Thomas K. Sherwood, Massachusetts Institute of Technology. *Chemical Engineering Series.* 278 pages, $3.50

In the preface to *Absorption and Extraction* the author outlines the purpose of the book, as follows: "The physical aspects of chemical engineering have to do principally with the transfer of heat and the interphase diffusion of material. Of the unit operations of chemical engineering, absorption, extraction, drying, humidification, and dehumidification are diffusional processes, and others may be cited in which diffusion plays a large part. It is the purpose of the present book to outline the underlying theory of these important processes and to deal particularly with the engineering problems connected with the design and operation of equipment for absorption and extraction."

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250-Watt Dome Reflector

For general industrial lighting applications where mounting heights of from eight to eighteen feet are encountered, the *Westinghouse* Enclosed Dome Type Reflector for 250-watt mercury lamp has been designed.

It consists of an 18″ diameter porcelain enameled dome type reflector with various types of hood mountings, and a dust-tight hinged glass cover. The convex lens used in the cover is acid etched on the inside and smooth on the outside. The entire assembly provides a wide uniform distribution of light so necessary for low mounting types of reflectors, and the diffusing lens minimizes the glare from the lamp.

The reflector is drawn from 24-gage iron sheet. One ground coat of porcelain enamel is applied all over, two coats of white porcelain enamel inside and one green coat outside with black bead provide the reflecting surface and covering. A medium socket with high heat wax and nickel plated interior is rigidly mounted in the hood to properly locate the lamp in the reflector.

The glass cover is hinged directly to the reflector bead, supported at three points. It is released by unsnapping two latches. A heavy waterproof felt provides a gasket between reflector and lens.

New Du Pont Plastic Shown at Children's Fair

A new crystal-clear plastic, developed recently by the *du Pont Company*, is shown among the four hundred seventy exhibitions entered in the Ninth Children's Science Fair, sponsored by the American Institute of the City of New York and held annually at the American Museum of Natural History. This Fair was in progress during the week of May 9 to 16. The variety and scope of exhibit subjects is practically unlimited, the only requisite being that each must fall within the field of science. The entries are made by high-school students in and near New York City, and the exhibits are planned and constructed in some cases by individual students, and in other cases by groups. This Fair, which aims to promote creative work in science among young people, has been attracting increasingly widespread attention among educational and scientific groups.

"Lucite," the new crystal-clear plastic, was the subject of two exhibits, one in the chemical group, and the other in the physics group. This thermoplastic resin looks like quartz crystal and has many of its qualities. In the chemistry exhibit, titled, "New Plastics," was included a bottle of the methyl methacrylate polymer, from which the finished plastic is made into various molded objects. The polymer is in the form of coarse white granules. A rod and discs of Lucite, made from methyl methacrylate monomer, a liquid which looks like distilled water, were also displayed. The raw materials for this plastic are coal, air, and water. In another section of the same display was seen cellulose acetate molding powder, and samples of the finished plastic made from it.

The physics exhibit of Lucite demonstrated a quality known as internal reflection. A curved rod, placed over a source of illumination, shows how the plastic transmits light around bends, without diffusion from the sides. The light can be seen coming out at the end of the rod only. Similarly a tube of Lucite plastic was placed over a light. The light travels through the plastic and is visible at the top edge of the tube.

These two exhibits of Lucite, which were planned and executed by the Girls' Commercial High School, Brooklyn, New York, were among the twelve out of the total four hundred seventy chosen by the New York Museum of Science and Industry to be taken to their own halls for a two-weeks' exhibition.

The Children's Science Fair also included an especially well-executed exhibit presented by the students of the Jamaica High School on the fixation from the atmosphere of nitrogen which is later converted into nitric acid.

Other subjects shown, of interest in the chemical field, included the steps in making a casein plastic and a phenol-formaldehyde plastic; rubber, as a raw material, some chemicals used to make it useful, and some types of manufactured articles made from it; a chart showing a few of the products derived from coal tar; a miniature reproduction of a chemical laboratory; and a four-sectioned turntable displaying materials that have to do with perfumes, cosmetics, asbestos, and rubber.

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pH Papers

The Lea Company, Waterbury, Connecticut, have placed on the market a new method for the determination of pH by the use of pH papers which permit visual quantitative determination of the acid or alkaline content of solutions. They are as fast as the well-known Litmus papers and give accurate quantitative results at a glance. Several ranges, as follows, are available: (1) 5.2 to 6.7; (2) 3.6 to 5.0; (3) 3.7 to 5.3; (4) 1.2 to 3.4; (5) 0.9 to 1.5; (6) 9.5 to 11.0; (7) 11.0 to 13.5.

These papers are very handy not only in the laboratory but in the plant where control of acidity or alkalinity in production must be maintained. The price is $7.50 per box of two hundred strips.

Trade Periodicals

SILICATE P's & Q's, Vol. 17, No. 6, 1937. *Philadelphia Quartz Co., 121 South Third St., Philadelphia.* 2 pp., 21.5 × 28 cm.

MACHINING MONEL, NICKEL AND INCONEL, Bulletin T-12, March, 1937. *The International Nickel Co., Inc., 67 Wall St., New York City.* 14 pp., 21.5 × 28 cm.

THE EDUCATIONAL FOCUS, Vol. 8, No. 1. *Bausch & Lomb Optical Co., Rochester, New York.* 22 pp., 15.5 × 23.5 cm. Profusely illustrated.

BAUSCH & LOMB MAGAZINE, Vol. 13, No. 1, 1937. *Bausch & Lomb Optical Co., Rochester, New York.* 22 pp., 21.5 × 28.5 cm. Profusely illustrated.

THE MERCK REPORT, Vol. 46, No. 2. *Merck & Co., Inc., 161 Sixth Ave., New York City.* 24 pp., 21.5 × 28.5 cm.

THE LABORATORY, Vol. 8, No. 4. *Fisher Scientific Co., Pittsburgh.* Pp. 50–64, 15.5 × 22.5 cm.

MONSANTO CURRENT EVENTS, Vol. 16, No. 1. *Monsanto Chemical Co., St. Louis.* 28 pp., 21.5 × 28.5 cm.

CENCO NEWS CHATS, No. 14. *Central Scientific Co., 1700 Irving Park Blvd., Northcenter Station, Chicago.* 15 pp., 19.5 × 27.5 cm.

TRENT LEAFLET TC-30 of *Harold E. Trent Co., 618–640 North 54th St., Philadelphia.* Pp. 13–4, 20 × 28 cm.

NICKELSWORTH, Vol. 1, No. 2, 1937. *International Nickel Co., Inc., 67 Wall St., New York City.* 8 pp., 21.5 × 28 cm.

THE NEW JERSEY ZINC ALLOY POT, Vol. 5, No. 3. *The New Jersey Zinc Company, 160 Front St., New York City.* 8 pp., 21.5 × 28 cm.

LAUCKS NOTEBOOK, Vol. 2, No. 4. *Laucks Laboratories, Maritime Building, Seattle, Washington,* and *Laucks Laboratories, Ltd., 1206 Homer St., Vancouver, B. C.* 4 pp., 21.5 × 28 cm.

SHOP AND LABORATORY, Vol. 1, No. 5. *Micro Instrument Co., Cambridge, Massachusetts.* 8 pp., 15 × 22 cm.

THE DUTCH BOY QUARTERLY, Vol. 15, No. 1, 1937. *National Lead Company, 111 Broadway, New York City.* Pp. 1–8, 19 × 27 cm.

INCO, Vol. 14, No. 3. *The International Nickel Co., 67 Wall St., New York City.* 34 pp., 22 × 29.5 cm.

WHITE METAL NEWS LETTER, Vol. 7, No. 2. *The International Nickel Co., Inc., 67 Wall St., New York City.* 1-page information sheet. 29.5 × 52.5 cm.

SYNTHETIC ORGANIC CHEMICALS, Vol. 10, No. 3. *Eastman Kodak Co., Rochester, New York.* 4 pp., 14 × 21 cm.

ESSO OILWAYS, April, 1937. *Standard Oil Company of New Jersey, Newark, N. J.* 21 pp., 21.5 × 28 cm.